RATIONALE FOR THE DEVELOPMENT OF SOIL, DRINKING WATER AND AIR QUALITY CRITERIA FOR LEAD

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Report prepared by:

Standards Development Branch
Ontario Ministry of Environment and Energy

December 1994

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LIST OF ABBREVIATIONS

MOEE	Ministry of the Environment & Energy
ATSDR	Agency for Toxic Substances & Disease Registry
IQ	Intelligence Quotient
MDI	Mental Development Index
ALA	Aminolevulinic Acid
ALAD	δ-Aminolevulinic Acid Dehydratase
IOC	Intake of Concern
CDC	Centers for Disease Control
LOAEL	Lowest Observed Adverse Effect Level
μg	Microgram (one-millionth of a gram)
dL	Decilitre (one-tenth of a litre)
ULN	Upper Limit of Normal
OTR	Ontario Typical Range
ODWO	Ontario Drinking Water Objective
NDMA	Nitroso-dimethylamine
PbB	Blood Lead
DWSP	Drinking Water Surveillance Program
BAT	Best Available Technology
BATEA	Best Available Technology Economically Achievable
AAQC	Ambient Air Quality Criteria

PREFACE

This report was originally published and distributed in January 1994, as supporting documentation for a public consultation on revised environmental standards for lead. The report, along with the *Scientific Criteria Document for Multimedia Standards: Lead* underwent a 90 day public review period conducted by the Minister's Advisory Committee on Environmental Standards (ACES). After taking into consideration information contained within the supporting documentation and the comments received during the public consultation, ACES made its recommendations regarding revised environmental standards for lead to the Minister in a report entitled *Soil, Drinking Water and Air Quality Criteria for Lead - Recommendations to the Minister of the Environment and Energy*. The revised standards for lead adopted by the Ministry are provided in the following table.

Recommended Multimedia Standards and Guidelines for Lead

Type of standard/guideline	Previous value	Revised value
Soil - Decommissioning Guidelines		
residential/parkland	500 ppm	200 ppm
agricultural	500 ppm	200 ppm
industrial/commercial	1000 ppm	1000 ppm
Ontario Drinking Water Objective	10 ppb	10 ppb
Air - Ambient Air Quality Criteria (Reg. 337)		
30 day AAQC	3 $\mu g/m^3$	0.7 $\mu g/m^3$
24 hour AAQC	5 $\mu g/m^3$	2 $\mu g/m^3$
Air - Point of Impingement Standard (Reg. 346)		
½ hour POI	10 $\mu g/m^3$	6 $\mu g/m^3$

Of the standards and guidelines presented in the table, only the agricultural soil clean-up guideline is different than the value recommended in this report. While this document recommends a value of 60 ppm, information received during the consultation indicated there may be some degree of uncertainty regarding the extent of lead uptake by crops in agricultural soils in Ontario. Moreover, submissions received indicated that a value of 60 ppm, if implemented, might have significant socio-economic impacts on the farming community in Ontario. In light of these issues, ACES recommended that the agricultural soil guideline be set at 200 ppm, a value consistent with the revised residential guideline. While ACES recommended

that 200 ppm be established as an interim guideline, the Ministry has adopted this value until further scientific and socio-economic studies support a lower value.

ACES also made recommendations for establishing goals and timelines for reducing the standards for air, drinking water and soil below the values recommended. The Ministry has concluded that these reductions are goals that may not be achievable in the timeframe specified by ACES and will require additional study. As the most effective means of reducing exposure to lead is through concerted education campaigns which target areas of high risk and address all potential routes of exposure, the Ministry will continue to advocate and support public education measures aimed a reducing lead exposure.

November 24, 1994

EXECUTIVE SUMMARY

As part of its regulatory mandate, the Ministry of Environment and Energy (MOEE) establishes and enforces standards and guidelines for environmental quality. This document provides the rationale for recommending a revised drinking water objective, soil clean-up guidelines and air quality standards and guidelines for lead which are protective of human health and the environment. This document primarily deals with risk management and policy issues related to the establishment of standards and guidelines for lead. A separate document entitled *Scientific Criteria Document for Multimedia Standards Development: Lead* provides a detailed discussion of the toxicological assessment for lead and the levels of exposure for people in Ontario.

Lead is a toxic heavy metal which has had widespread historical use. At one time, lead was contained in a number of products including: solder used in cans and plumbing, gasoline, paints and certain pesticides. The past several decades have demonstrated a marked reduction in lead exposure for the general population. This reduction can largely be attributed to the phase-out of leaded gasoline. However, while exposure to lead has greatly diminished, several recent studies on the health effects of lead suggest adverse effects can occur at levels of exposure previously considered safe.

The effects of lead on human health are varied. Exposure to lead can adversely affect many organ systems including the reproductive, renal, cardio-vascular, blood forming and developing central nervous systems. Young children (aged six months to 4 years) are considered at greater risk of lead exposure due to the fact that they absorb lead more efficiently than adults and, on a body weight basis, they have a greater daily intake. Several studies which have examined blood lead levels (as an indicator of exposure) in children have suggested that behaviourial effects and learning deficits can occur at levels as low as 10 µg/dL; levels previously regarded as safe. It is also possible however, that adverse health effects may occur at blood lead levels below 10 µg/dL. Based on these studies, many jurisdictions including the MOEE recognize a blood lead level of 10 µg/dL as a blood lead level of concern. It has been estimated that approximately 18,000 children in Ontario may have blood lead levels greater than 10 µg/dL.

For the purposes of setting environmental standards and guidelines, the MOEE has recommended the use of an Intake of Concern (IOC_{pop}) for lead. The IOC_{pop} of 1.85 µg/kg/day was derived by determining the daily intake of lead that roughly corresponds to a blood lead level of 10 µg/dL (3.7 µg/kg/day) and applying a factor of 2 to account for variability in the population and uncertainty. The use of an IOC_{pop}

of 1.85 µg/kg/day is meant to be preventative to ensure that on a individual basis, children's blood lead levels do not exceed 10 µg/dL.

To establish environmental quality criteria for soil, drinking water and air, a "multimedia" approach was used. This approach considers all sources of exposure (media) including food, water, soil and air concurrently. The IOC_{pop} was allocated to the various media on the basis of the exposure assessment conducted for lead. The exposure assessment for children in Ontario indicates that approximately 24% of exposure results from food; 64% results from soil, 11% from drinking water and less than 1% results from direct inhalation. For deriving desirable health-based limits for each media, the allocation factor and consumption rate of each media is applied to the IOC_{pop}. While the desirable health-based limits define the starting point for the derivation of revised standards and guidelines, other factors such as technical feasibility, background levels in Ontario and the costs associated with meeting such criteria were also examined. The resulting standard or guideline attempts to strike a balance between the desirable health-based limits and these other factors. The recommended standards and guidelines are summarized in the following table.

Recommended Multimedia Standards and Guidelines for Lead

Type of standard/guideline	Current Value	Recommended Value
Soil Clean-up Guidelines		
residential/parkland	500 ppm[1]	200 ppm
agricultural	500 ppm	60 ppm* (see Preface)
industrial/commercial	1000 ppm	1000 ppm
Ontario Drinking Water Objective	10 ppb[2]	10 ppb
Air - Ambient Air Quality Criteria (Reg. 337)		
30 day AAQC	3 µg/m³	0.7 µg/m³
24 hour AAQC	5 µg/m³	2 µg/m³
Air - Point of Impingement Standard (Reg. 346)		
½ hour POI	10 µg/m³	6 µg/m³

[1] ppm - parts per million (µg lead per gram of soil)
[2] ppb - parts per billion (µg lead per litre of water)

The recommended soil clean-up guidelines for incorporation in the Ministry's decommissioning policy are 60 ppm for agricultural sites, 200 ppm for residential and parkland sites and 1000 ppm for commercial/industrial sites. The primary consideration on which these values are based is health. While it is recognized that, due to the many historical uses of lead, a residential limit of 200 ppm will be exceeded in many older urban residential areas, it should be stressed that the revised

clean-up guidelines are not to be considered values which when exceeded trigger clean-up. Rather, the revised guidelines apply in the context of the Ministry's Decommissioning Policy. Recommendations for dealing with exceedances in residential situations are provided.

For drinking water, it is recommended that the Ontario Drinking Water Objective (ODWO) for lead remain unchanged from its present value of 10 μg/L. While this is higher than the desirable health-based criteria of 4.5 μg/L, continuous exposure to this level represents an approximate increase in total lead exposure of only 11% over a limit defined by the IOC_{pop}. The main consideration on which this recommendation is based is the potential cost associated with lowering the ODWO for lead. The presence of lead in drinking water results primarily from the corrosion of lead-based plumbing material used throughout the distribution system. Potential cost estimates for controlling the corrosivity of water in those areas of the province where it might be a contributing factor to lead in drinking water range as high as $1.5 billion. This would be reflected in annual fee per household of $5.94 to $2,394 depending on the size of the municipality affected. Monitoring data from Ontario's Drinking Water Surveillance Program (DWSP) indicates that routine flushing of pipes is an effective means of reducing the levels of lead in drinking water.

For air, a value of 0.7 $\mu g/m^3$ for a 30 day average ambient air quality criteria (AAQC) is recommended. Using empirically derived conversion factors, this translates to a 1/2 hour point of impingement standard of 6 $\mu g/m^3$ and a 24 hour average AAQC of 2 $\mu g/m^3$. A value of 0.7 $\mu g/m^3$ for a 30 day average is based on what is considered technically and economically achievable by a model secondary lead smelter, the one industrial sector which will be affected by revised air standards for lead. Although the recommended AAQC is higher than the desirable health-based criteria of 0.05 $\mu g/m^3$, continuous exposure to this level represents an approximate increase in total lead exposure of only 14% over a limit defined by the IOC_{pop}. This is because direct inhalation represents only a minor percentage of total lead exposure. The impact that such a criterion will have on soil through deposition was also examined. The long-term impact that a limit of 0.7 $\mu g/m^3$ is expected to have on soil lead levels is an increase in lead content of 185 ppm over a period of 50 years.

The benefits of reducing lead exposure through the use of revised standards and guidelines was also examined. Based on the relationship between a child's exposure to lead and IQ and the relationship between IQ and long-term earning potential, a benefit in economic terms can be demonstrated. However, there is considerable uncertainty in understanding the degree to which reduced environmental standards for lead will affect exposure for the general population. Because of the many historical uses of lead, and its persistence in the environment, exposure to lead can be expected to be a significant public health issue for many years to come. While

environmental standards and guidelines for lead will play a role in reducing exposure in the long-term, the most effective means of addressing the health risks of lead is considered to be through concerted education programs which target areas of high risk and address all potential routes of exposure.

Several potential sources of lead exposure fall outside of the regulatory mandate of the MOEE. Recognizing these sources can be a significant hazard, general recommendations for dealing with these sources are provided.

SUMMARY OF RECOMMENDATIONS

Recommendation 1:

The revised residential/parkland soil guideline be set at 200 ppm, a value which, based on exposure modelling, will protect the health of children between the ages of six months to four years. As children are the most sensitive receptors for lead, this level will also protect the general population. The revised guideline is technically feasible because certain soil remediation techniques can achieve levels of 200 ppm.

Recommendation 2:

The exposure to lead through the consumption of backyard vegetables grown in lead contaminated soil should not be a driving factor for a revised residential/parkland guideline. Although such food can be a source of lead exposure, it is felt that the degree of uncertainty in estimating the amount of home-grown vegetables eaten by Ontario children aged 0.5 to 4 years in addition to the overall uncertainty in predicting the influence of soil lead on blood lead levels is unacceptable when compared to the potential increase in costs associated with a lower residential soil clean-up guideline. It is recommended that both of these issues be the subject of further research.

Recommendation 3:

The industrial/commercial decommissioning soil guideline for lead should remain at its present value of 1000 ppm.

Recommendation 4:

The agricultural soil criterion for lead should be reduced from its present value of 500 ppm to 60 ppm to protect food crops from lead contamination. The revised value of 60 ppm is close to what is considered background for agricultural soils and is consistent with the recommended maximal soil lead concentration under the *Guidelines for the Utilization of Sewage Sludge on Agricultural Lands.* (see Preface)

Recommendation 5:

The current distinction between coarse and fine-textured soils should be discontinued for lead. This is because the revised lead guidelines are based on protection of human health and the affect of soil texture on the availability of lead to humans is not well enough understood for the development of quantitative relationships. The Ministry of Environment and Energy is currently sponsoring research to better understand this issue.

Recommendation 6:

Special consideration should be given to ensuring that the levels of lead in covering soil used for community or commercial play areas, like sand lots, baseball diamonds and sand boxes, is limited to the greatest extent possible. Soil quality consistent with rural background soil should be used for these areas wherever possible.

Recommendation 7:

The Ontario Drinking Water Objective remain unchanged from its present value of 10 µg/L. The rationale for this recommendation is that DWSP data, while indicative of trends across the province, is not representative of homes on a particular distribution system. As a result, there may be areas of the province where the levels of lead in drinking water exceed a desirable health-based criteria. The potential cost for corrosion control to address these areas and the impact on other key treatment processes need to be carefully evaluated prior to recommending revising the ODWO for lead. While the ODWO for lead is higher than the desirable health-based criteria, continuous exposure to this level represents an increase in total exposure of only 11% over a limit defined by the IOC_{pop}.

Recommendation 8:

Municipalities, in cooperation with the MOEE, undertake a comprehensive drinking water survey which is representative of

each distribution system for lead levels in both flushed and standing samples. The results will be used to assess the corrosivity of the water. Where the lead concentration in standing water greatly exceeds the lead concentration in the flushed water, municipalities implement, in cooperation with the appropriate public health agencies, education programs for those areas of high risk. Where results indicate that greater than 10% of flushed samples are in excess of 10 µg/L, municipalities implement appropriate measures to control the corrosiveness of water.

Recommendation 9:

For individual households which have a concern about the presence of lead in drinking water, it is recommended that water used for consumption be drawn from taps which have been flushed of standing water. If implemented properly, the recommendation for flushing need not be inconsistent with water conservation programs. Section 5 provides further details on the best ways for implementing home flushing programs.

Recommendation 10:

School Boards in Ontario maintain a consistent and regular flushing and monitoring program within their schools to reduce children's potential exposure to lead.

Recommendation 11:

A revised ambient air quality criterion averaged (arithmetic mean) over thirty days be set at 0.7 $\mu g/m^3$. This represents an emission limit based on Best Available Technology Economically Achievable (BATEA) for a model secondary lead smelter. Since inhalation is considered to be a minor route of exposure, a criterion of 0.7 $\mu g/m^3$ would represent an increase in total lead exposure of only 14% over a limit defined by the IOC_{pop}. The impact on soil using such a standard is estimated to be an approximate increase in lead levels of 185 ppm at the point of impingement realized over 50 years.

Recommendation 12:

Based on the empirically derived conversion factors of 3 and 3 respectively, a half-hour point of impingement standard of 6 $\mu g/m^3$ and a 24 hour ambient air quality criterion (AAQC) of 2 $\mu g/m^3$ are recommended.

Recommendation 13:

Because of the concern associated with emissions from the lead industry, the Ministry continue air monitoring near industrial point sources of lead emissions.

Recommendation 14:

Because of the uncertainty in understanding the long-term impact on soil resulting from atmospheric deposition, the Ministry, in cooperation with the lead industry, undertake a comprehensive soil monitoring program in the vicinity of industrial point sources of lead where lead has been identified as a concern.

Recommendation 15:

The Ministry, in cooperation with other regulatory agencies, sponsor research into innovative means for controlling fugitive emissions from industrial sources of lead.

Recommendation 16:

The standards, guidelines and objectives proposed in this report be reviewed as new information becomes available.

1.0 INTRODUCTION

The Ontario Ministry of Environment and Energy is responsible for achieving and maintaining a quality of the environment, including air, water and land, that will protect human health and the ecosystem, and will contribute to the well being of the people of Ontario. One of the means by which the Ministry fulfils its mission is by setting standards to control the levels of pollutants in air, water and soil. The Ministry obtains its authority to do this under the *Environmental Protection Act* and the *Ontario Water Resources Act*.

Lead is an historically recognized toxic substance that occurs naturally in the earth's crust, but whose presence at high levels in the environment is largely due to human activities. Metallic lead and its compounds have many desirable properties, such as resistance to corrosion, that have led to their extensive use in industry and in the home. At one time, lead was contained in a wide variety of products, such as food cans, water pipes, gasoline, paints, plastics, ammunition, pesticides and batteries. Today, use of lead has greatly declined due to advances in technology and the availability of safe alternatives. However, its widespread use in the past and its persistence in the environment, mean that Ontarians are still exposed to low levels of lead in air, drinking water and soil. Some citizens may be at risk of higher exposure if they use consumer products containing lead, if they live in an urban residential area, if they have elevated levels of lead in drinking water or if they eat food grown in soil with high levels of lead.

In Canada, both the federal and provincial governments have regulated lead in many different media, including ambient air, drinking water, soil, sludges, sediments and consumer products. These efforts have been very successful in reducing environmental lead exposure over the past 20 years. For example, the blood lead levels of Toronto children in 1990 were three times lower than those of city children in 1984; much of this encouraging decline is attributed to the phase-out of leaded gasoline. Nevertheless, lead continues to be an environmental contaminant of concern for many jurisdictions. As recently as 1991, the Department of Health and Human Services of the Agency for Toxic Substances and Disease Registry (ATSDR) ranked lead as its most important priority hazardous substance based toxicity and potential for exposure. In Ontario, it has been estimated that greater than 18,000 children may be a risk from elevated exposure to lead (MOEE, 1993).

The Ministry has decided to review its current limits for lead in ambient air (amended in 1974), drinking water (1991) and soil (1988) for two main reasons.

First, the ways in which Ontario residents are exposed to lead have changed dramatically in the last decade. The relative contribution of air to the overall lead exposure has decreased significantly in the last decade. However, since lead persists in soil, this exposure pathway takes on greater significance. Second, and more importantly, however, several recent studies suggest that learning or behavioral deficits can occur in young children at levels of exposure previously believed to be safe. Therefore, while the levels of lead in the environment have gone down so too have the exposure levels at which adverse health effects have been reported.

The Hazardous Contaminants Branch of the Ministry has completed a comprehensive scientific review of the effects of environmental levels of lead on human health. The findings are contained in an accompanying document entitled *Scientific Criteria Document for Multimedia Standards Development: Lead* (approximately 330 pages). Based on an assessment of lead's toxicity, the Scientific Criteria Document proposes an Intake of Concern (IOC_{pop}) for lead which forms the foundation on which the revised environmental criteria are based. Also provided in the Scientific Criteria Document is an in-depth assessment of Ontarians' exposure to this pollutant. The exposure assessment estimates the total amount of lead that reaches Ontario residents through food, air, water, consumer products, soil and dust.

The purpose of this document, *Rationale for the Development of Soil, Drinking Water, and Air Quality Criteria for Lead,* is to propose a set of revised environmental limits for lead based on the findings contained in the Scientific Criteria Document. These include soil clean-up guidelines, an Ontario Drinking Water Objective and air quality standards and guidelines. The terms standards, guidelines and objectives tend to be used interchangeably. However, legally the definitions are quite distinct. Standards refer to legally enforceable criteria specified under regulation (i.e. Regulation 346), while guidelines and objectives represent desirable limits specified under regulation or policy (i.e. Regulation 337, Ontario Drinking Water Objectives). Practically speaking however, the three terms refer to limits of pollutants the Ministry, through a variety of means, uses to maintain the quality of the environment that will protect human health and the environment. The approach taken to setting such limits for lead is called the *multimedia approach.* This is because all potential routes of exposure are considered simultaneously. Approaches which only consider a single route of exposure may significantly underestimate the risk to human health.

The proposed limits for lead attempt to strike a balance between the identified risks to human health and practical or socioeconomic implications. This docu-

ment contains a summary of information contained in the Scientific Criteria Document on the health effects of low levels of lead on young children, who are the population most sensitive to its adverse effects, and describes the derivation of the intake level of concern. The ways in which Ontarians are exposed to lead are described and the risks to health are estimated. Issues, such as technical achievability and cost, are explored for each proposed new standard. In addition, recognizing that people may be exposed to lead in many different ways, other than through air, water and soil, a set of general recommendations has been provided both to help individuals minimize their exposure to lead and to guide agencies that have regulatory authority over paint, food and other consumer products.

This document recommends environmental limits for soil, drinking water and air based on an assessment of risk to human health. It is recognized that there are other organisms that may be affected by the presence of lead in the environment (animals, plants). Although there may be some sensitive species, most plants and animals will be protected from adverse effects under the proposed limits. A thorough literature search indicated that most terrestrial plants and animals would be protected at soil levels which are protective of human health. The Ministry is in the process of producing two separate documents entitled *Scientific Criteria Document for the Derivation of Water Quality Guidelines: Alkylleads* and *Scientific Criteria Document for the Derivation of Water Quality Guidelines: Inorganic Lead* which describe the toxicity of lead compounds towards aquatic organisms and proposes limits in surface waters which are considered protective of these species.

2.0 HEALTH RISKS OF ENVIRONMENTAL LEAD EXPOSURE

2.1 Effects of Lead on Human Health

Descriptions of lead's toxicity have been recorded from ancient times to the present and a large body of scientific literature is available on its effects on human health. Lead affects many different organ systems in the human body; including the central nervous, reproductive, renal, cardiovascular and blood-forming or haematopoietic systems. In order to set environmental standards, however, one must identify the health effects that occur at the lowest levels of exposure, or the critical endpoint. Next, those persons most sensitive to the adverse effects of lead must be identified. If the standards are set to protect the health of this most sensitive subpopulation, then these standards should also protect the health of the general Ontario population.

The health effects that occur in children and adults at different levels of blood lead (PbB) are summarized in Table 1. Even at blood lead concentrations below those associated with clinical poisoning (recently redefined to include subclinical effects), lead gives rise to characteristic biochemical changes.

As can be seen from Table 1, health effects appear to occur at lower blood lead levels in children than in adults. Children are believed to be more sensitive to lead for many reasons. First, the central nervous system is especially vulnerable to toxins during prenatal and early postnatal development. Furthermore, children absorb lead more readily than adults; and, because of their smaller body size, their intake on a body weight basis is greater. The most sensitive populations are thus taken to be the fetus, pregnant women (as surrogates of fetal exposure), and children under the age of four years.

In the 1980's, several well designed epidemiological studies explored the effects of low levels of lead exposure (PbB less than 25 µg/dL) on children's health. The studies showed that lead exposure in pregnancy or early childhood was associated with learning and behavioral deficits, these deficits being measured by a variety of means most frequently Bayley's MDI (Mental Development Index) scores. Many other undesirable effects were also observed in the same range of blood lead concentrations, including decreased birth weight; reduced gestational age; growth retardation; and interference with the blood forming system.

Epidemiological studies can only demonstrate *association* of a factor with an effect, rather than *causation*. Thus, whether or not these adverse health effects

were caused by the children's exposure to lead has been the subject of scientific debate. Criticism of these studies have focused on the relative weakness of the association when compared to other socio-demographic factors, such as maternal IQ, but the consistent positive findings by several independent research teams supports exposure to lead as the cause of these adverse health effects observed.

Table 1 Summary of Health Effects Observed at Different Blood Lead Levels

Observed Health Effect	Lowest Observed Effect Level PbB (μg/dL)	
	Children	Adults
Encephalopathy; acute kidney damage	80-100	100-120
Peripheral neuropathy; Frank anemia; gastrointestinal effects, including colic	70	80
Chronic kidney damage	60	100-120
Central nervous system effects; reduced haemoglobin; increase in metabolites such as urinary ALA and coproporphyrins	40	50
Peripheral nerve dysfunction	30	40
Elevated blood pressure	-	30
Lower IQ	25	-
Elevation of blood (haem) metabolites, such as erythrocyte protoporphyrin	15-20	25-30
Behavioral deficits; reduced birth weight; reduced gestational age; growth retardation up to 7 to 8 years of age	<10-15	-
Reduction of certain enzymes (ALAD)	<10-15	<10

ALA = Aminolevulinic Acid ALAD = δ-Aminolevulinic Acid Dehydratase

As demonstrated in Table 1, low levels of lead are also associated with adverse health effects in adults. Although the epidemiological findings are not consistent, an association between lead exposure and elevated blood pressure has been reported, particularly in middle-aged men. These effects appear to occur at blood lead levels of 30 µg/dL, levels considerably greater than the levels associated with learning and behavioral deficits in children.

It should also be mentioned that lead has been reported to be an animal carcinogen, with many independent studies reporting a high incidence of distinctive kidney tumours in rodents exposed to high doses of lead. Carcinogenicity, however, was not chosen as the critical endpoint because the rodent tumours occurred at exposure levels much higher than those that give rise to learning and behavioral deficits in children. Furthermore, the use of large sets of human data for establishing limits protective of human health is preferable to predicting the effects on human health from a series of animal studies.

In summary, therefore, for the purposes of setting new environmental standards for lead, children under the age of four years were chosen to be the most sensitive population and learning and behavioral deficits to be the critical endpoint. Thus, standards protective of young children should also protect adults against the effects of lead on blood pressure, since adults are less sensitive to the adverse effects of lead.

The next step in developing environmental standards for lead is to define an exposure level, or intake of concern (IOC) for lead, that is considered protective of the health of children. This is done by relating levels of exposure to lead to the blood lead concentrations of the sensitive population. Unfortunately, researchers have not been able to develop an equation that can precisely relate children's blood lead levels to IQ scores or other developmental indices. Several studies report a difference of one to two IQ points for the range 15 to 30 µg/dL (reviewed in MOEE, 1993). This agrees with the Centers for Disease Control (CDC) estimate that every 10 µg/dL increase in blood lead leads to an IQ deficit of approximately 2.5 points. Studies on mental development have suggested deficits of 2 to 8 MDI (Mental Development Index) points for every 10 µg/dL increase in blood lead. Studies on growth and development and on gestational age have had similar findings. The relative risk of pre-term delivery, or delivery before the 37^{th} week of pregnancy, increased 2.8 times for every 10 µg/dL increase in maternal blood lead; and at blood lead levels greater than 14 µg/dL, the risk of pre-term delivery was 4.4 times that at 8 µg/dL or less. In summary therefore, learning and

behavioral deficits, as well as problems in growth and development, appear to occur at blood lead levels of 10 to 15 µg/dL or less.

A blood lead level of 10 µg/dL was chosen by the Ministry to be the Lowest Observed Adverse Effect Level (LOAEL) for children. This agrees with the "blood lead level of concern" used by a number of agencies and jurisdictions in Canada and the United States. This value, however, should not be regarded as a threshold value below which no adverse health effects will occur. No threshold has as yet been established for learning and behavioral deficits in children, although one may exist below the range of 10 to 15 µg/dL PbB. Certain biochemical changes, such as altered enzyme levels related to lead's toxic effect on the blood system, do not show a threshold effect even at very low PbB.

The intake level of concern for Ontario children (IOC_{pop}) which was used for the development of standards in this document was derived by estimating the lead intake that would result in a blood lead level of 10 µg/dL. This intake level was estimated to be 3.7 µg Pb/kg/day. This value was then divided by a safety factor of two which results in an IOC_{pop} of 1.85 µg/kg/day. This safety factor of two was used to account for potential variations within the population. Uncertainty in the derivation mainly stems from how accurately blood lead levels reflect an individual's actual exposure to lead. Because of the large body of human data used in the derivation, the overall uncertainty is believed to be low (MOEE, 1993).

The recommended intake of concern thus derived is 1.85 µg Pb/kg/day or 0.0018 mg Pb/kg/day. This is equivalent to a daily intake of about 24 µg Pb/day for a child aged 0.5 to four years. The IOC_{pop} should not be regarded as a threshold level below which no health effects will occur because the LOAEL on which it is based is not believed to be a threshold level. Rather, it is an intake level that corresponds to a blood lead level that is believed to present a low risk to children's health. In other words, if the population as a whole maintains an intake of lead below this IOC_{pop}, then it is anticipated that the vast majority of children will have blood lead levels less than 10 µg/dL and their health should be protected. Because adults have a lower uptake of lead than children, this IOC_{pop} should also protect adults, including pregnant women and the fetus. As mentioned, the LOAEL for lead used by various agencies is 10 µg/dL. This represents a blood lead level used by the CDC for community intervention. The philosophy behind the use of an IOC_{pop} is one of prevention rather than intervention.

2.2 Exposure of the Ontario Population to Lead

Ontario residents are exposed to lead through several different routes, including food, consumer products, ambient air, drinking water, soil and house dust. Overall exposure to lead has declined significantly in the past decade. Epidemiological surveys in the province suggest that children's exposure to lead has declined by at least 50% since the early 1980's. This is due largely to the elimination of leaded gasoline. In order to set new environmental standards, one must understand how Ontarians are currently exposed to lead.

The multimedia approach, which considers total exposure from all environmental media, was used to estimate the exposure of the Ontario population to lead. The levels and trends of lead in air, soil, and drinking water were obtained from recent provincial data, much of it from the Ministry's monitoring programs. Because lead levels in food have declined significantly in the past decade and 1985 is the most recent year for which Canadian dietary data are available, the current intake of lead from food was estimated using recent American data (1990). Details on the sources of data and the calculations are presented in the Scientific Criteria Document.

Previously, food was the greatest source of lead exposure because of the lead-based solder used in food cans. Using recent American dietary intake data to estimate 1993 exposure, Ontario children receive an estimated 6 µg Pb/day from food, which accounts for 24% of a child's total daily intake of lead. Soil and dust contribute proportionately more at about 64%. This was estimated by using observed data on soil lead levels and by assuming that children ingest an average of 80 mg soil each day. The resulting daily lead intake from soil and dust was thus calculated to be 16 µg/day or 1.2 µg/kg/day, making it by far the most important route of lead exposure for children.

Contribution from other exposure routes is less significant. Drinking water represents only 11% of total intake (3 µg/day or 0.23 µg/kg/day) and direct inhalation about 1% (0.15 µg/day or 0.011 µg/kg/day). Dermal absorption of lead is considered to be negligible.

Although the exposure assessment shows that the total exposure of the Ontario population to lead has declined dramatically over the past decade, the current daily lead intake from all major pathways for young urban children (0.5-4 years) is estimated to be 1.9 µg/kg/day. This is very close to the intake of concern of 1.85 µg/kg/day discussed in section 2.1. Therefore, the margin of safety for typical urban children in Ontario is small and could easily be

exceeded under higher exposure scenarios. This could include: living in the vicinity of industrial sources of lead emissions; elevated levels of lead in drinking water; consumption of vegetables grown in lead contaminated soil; exposure to lead-based paint through normal weathering or home renovations; and use of lead-containing consumer products.

Total daily exposure may be 25% greater for urban children living near an industrial source of lead and as much as 40% higher in areas with lead contaminated drinking water. Eating vegetables grown in lead polluted soil can result in lead intakes as large as direct ingestion of soil. Furthermore, exposure to certain consumer products with very high lead contents such as paints, ceramic glazes, or hobbyist materials, always carries a risk of clinical poisoning. Section 5 identifies other sources of lead and addresses minimizing this type of incidental exposure.

2.3 Multimedia Media Allocation of Exposure

The revised lead standards should support each other to keep children's exposure to lead below the intake level of concern (IOC_{pop}) of 1.85 µg/kg/day. In other words, together they should ensure that the sum of children's exposure to lead through air, drinking water and soil not exceed 1.85 µg/kg/day.

In order to develop standards to protect children's health, the IOC_{pop} was divided up or allocated to each of the four primary routes of exposure (soil, food, water, air). In splitting up this value between each of the media, it was assumed there was no transfer between media, for example, from air to soil. However, intermedia transfer is a consideration in the development of a revised ambient air standard. As explained in Section 2.2, the most recent Canadian dietary data were collected in 1985, but more accurate estimates of current exposure to lead in food were made using recent American data. Allocations were made as outlined in Table 2 and were used to derive revised soil clean-up guidelines, the Ontario Drinking Water Objective and ambient air standards and guidelines for lead.

Table 2 Media-specific Allocations of Lead Exposure for Derivation of Revised Lead Standards (MOEE, 1993)

Exposure Route	Medium-Specific IOC_{pop} (µg/kg/day)	Allocation
Food	0.44	24%
Soil	1.18	64%
Drinking water	0.20	12%
Ambient air	0.02	<1% (assume 1%)

3.0 DERIVATION OF ENVIRONMENTAL STANDARDS

3.1 Derivation of the Revised Soil Clean-up Guidelines for Lead

A key objective of this document is to recommend revised soil guidelines for lead to replace the current soil clean-up guidelines used by the Ministry. In developing the recommended guidelines, several factors are considered: the need to protect human health and the environment, cost, and technical feasibility.

Soil clean-up guidelines are applied in the context of the Ministry's decommissioning policy. This policy is meant to apply to sites which are dismantled, partially dismantled or mothballed as well as situations such as spills where clean-up is required in the absence of full-scale decommissioning activities. In these cases, the soil is remediated to a quality consistent with the anticipated land use of the site. Given the prevalence of lead in the environment, decommissioning guidelines should not be considered as values which, if exceeded, would automatically trigger a clean-up. Recognizing that exceedances of the current 500 ppm criterion are not uncommon in older urban residential areas and that exceedances of the revised standards are anticipated, recommendations for dealing with these situations are provided.

3.1.1 Application of Current MOEE Standards

The current soil clean-up guidelines for lead are listed in the publication *Guidelines for Decommissioning and Clean-up of Sites in Ontario* (MOEE, 1989). Values are presented in Table 3.

Table 3 Current Guidelines for Decommissioning and Clean-up of Sites in Ontario

LAND USE	GUIDELINE (ppm)	
	Medium and fine textured soil	Coarse grained soil
Agricultural, residential, and parkland	500	375
Industrial	1000	750

The guidelines were established by considering the following factors: animal and plant toxicity; observed concentrations in soil (Upper Limit of Normal); and limits used by other jurisdictions. Guideline values are lower for coarse grained soils, because metals tend to be more mobile and hence, more readily available for uptake by plants in this type of soil (MOEE, 1991). Further details on the rationale for these clean-up criteria are contained in the document, *Soil Clean-up Guidelines for Decommissioning of Industrial Lands: Background and Rationale for Development* (MOEE, 1991).

In addition to the decommissioning guideline for lead, the MOEE in 1987 established a soil clean-up guideline for lead in conjunction with a soil removal program carried out in the South Riverdale area of Toronto. The guideline was developed by a committee with representatives from all three levels of government, community public interest groups and the lead industry. After reviewing the available information on lead, the committee recommended that a residential clean-up level should lie between 500 and 1000 ppm. Based on this recommendation, the Minister accepted 500 ppm as the clean-up level. This criteria was applied as a trigger for remedial action in those homes where children had demonstrably elevated blood lead concentrations.

3.1.2 Soil Clean-up Criteria used in Other Jurisdictions

As a comparison, select clean up guidelines from other jurisdictions are presented in Table 4.

Table 4 Soil Clean-up Criteria from Other Jurisdictions

AGENCY	LIMIT	COMMENTS
USA		
Minnesota	300 ppm	bare soil standard considered protective of human and environmental health
Massachusetts	300 ppm	based on revised risk assessment taking into consideration most sensitive receptor

In the United States many of the worst contaminated sites are cleaned up under the Superfund program. Clean-up criteria are developed using a risk assessment approach for each site. The resultant criteria for clean-ups

involving lead, which are specified in the Record of Decision for each site generally lie in the range of 200-500 ppm. However limits as low as 20 ppm and as high as 420,000 ppm have been used (MOEE, 1993).

3.1.3 Derivation of Health-Based Criteria

Health-based standards are derived to protect the most sensitive receptor exposed to the contaminant. This sensitive population may vary with the type of site, depending, for instance, on whether the site is residential or industrial.

Residential/Parkland Sites -

For lead, the most sensitive receptor for residential/parkland soil is considered to be a child aged six months to four years. The multimedia exposure assessment for lead allocated 64% of a child's intake to direct ingestion of soil or dust (Table 2). To derive a soil lead level protective of this age group, this allocation factor was applied to the intake level of concern (IOC_{pop}) of 1.85 µg/kg/day using the equation below. Body weight was taken to be 13 kg, the average weight of a child in this age range. The soil consumption rate was set at 80 mg per day.

$$\text{Soil Guideline} = \frac{IOC_{pop} \times \text{Allocation Factor} \times \text{Body Weight}}{\text{Soil Consumption Rate}} \quad \textbf{[Equation 1]}$$

$$= \frac{1.85\ \mu g/kg/day \times 0.64 \times 13\ kg}{80\ mg/day}$$

$$= 192\ \mu g/g$$

Based on this derivation, the desirable health-based lead soil standard for residential soils would be 200 µg/g or ppm. This means that if a child weighing 13 kg ingests 0.08 grams of soil or dust each day, then a soil lead concentration of 200 ppm would limit the child's lead intake to less than 1.2 µg/kg/day, or 64% of the IOC_{pop} of 1.85 µg/kg/day.

Indirect Exposure - Vegetable Consumption

Indirect exposure to lead through the consumption of home grown vegetables may also be considered in deriving a residential soil clean-up guideline. Certain plants are able to absorb and store lead from soil so vegetables grown in lead-containing soil may therefore represent a significant route of exposure (Carlisle and Wade, 1992; MOEE, 1993). This potential exposure can be calculated by estimating the amount of homegrown vegetables eaten by a typical household. Again, the most sensitive receptor is a child aged six months to four years. The total exposure of 1.2 µg/kg/day allocated to soil-based pathways must be divided between the amount directly ingested in soil and that consumed in backyard vegetables. This relationship is expressed by the following equation:

$$1.2\ \mu g/kg/day = \frac{\text{Soil Guideline} \times [\text{Soil Consumption Rate} + (B_{prod} \times CR_{prod})]}{\text{Body weight}} \qquad \textbf{[Equation 2]}$$

where:

B_{prod} = bioconcentration factor of lead in vegetables
CR_{prod} = consumption rate of backyard produce

The bioconcentration factor was set at 0.0033 per fresh weight (range 0.0002 - 0.006). This is an average of values determined experimentally for several types of vegetables (MOEE, 1993). In calculating CR_{prod}, it was assumed that a typical backyard garden is 30 square metres and produces 42 kg of produce per year. If this amount is fully consumed by a family of four, it represents 14% of their annual vegetable intake. For a child, this amounts to about 14 grams of homegrown vegetables per day. Using previous values for soil consumption rate (80 mg/day) and average body weight (13 kg), **yields a desirable health-based soil guideline of approximately 124 ppm.**

Agricultural Soil -

Under the current decommissioning guidelines, agricultural soils are considered to be equivalent to residential and parkland soils. This treatment is appropriate only when the anticipated exposure scenario for the most sensitive receptor is the same for both soil types, in other words, a child under four years of age who ingests 80 mg of soil a day. For agricultural soils, however, two factors must be considered: the exposure of persons living on the farm, and the ability of the land to produce foods free of chemical contaminants.

Considering the observation that vegetables grown on lead bearing soil can be a significant route of exposure, it follows that the criterion for agricultural soil should be lower than residential/parkland soil. Using equation 2 described above and incorporating a value of 100% for vegetable consumption derives a **desirable health-based criterion of approximately 34 ppm**. As discussed in the following sections, this is considered to be within a range considered to be representative of background concentrations for lead in agricultural soil.

Other than the MOEE decommissioning guidelines, the only other limits for lead which have been established for agricultural soils are the *Guidelines for Sewage Sludge Utilization on Agricultural Lands* (OMAF and MOEE, 1992). These are intended to prevent build-up of toxic concentrations of heavy metals on agricultural lands through use of sewage sludge. The values were established by an expert committee who set the recommended maximum soil concentrations as multiples of the average metal concentrations found in uncontaminated soil. The appropriate multiple (a factor ranging from 2 to 8) for a given metal was based on the degree of plant uptake from soil. The guideline for lead was set at 60 ppm, four times the average concentration found in uncontaminated agricultural soil.

Commercial/Industrial Soil -

For industrial soils, a typical receptor is considered to be an adult worker who only spends a portion of the day exposed to the site. Therefore, a health-based, industrial soil guideline for lead may be calculated using the appropriate soil ingestion values and average body weights for adults in Equation 1. Incorporating a soil ingestion value of 20 mg/day and a body weight of 70 kg yields a health-based criterion greater than 4100 ppm. This value is considerably higher than the current commercial/industrial decommissioning guideline of 1000 ppm and approaches soil lead levels which may have adverse effects on certain plants and soil dwelling organisms. A health-based value would be even higher if consideration were given to the fact that workers only spend a portion of their day exposed to the site. Therefore an argument can be made that, based on this exposure scenario, the commercial/industrial guideline could be raised from its present value of 1000 ppm. However, one factor which is not taken into consideration is the potential off-site impact on residential and parkland sites resulting from blowing soil and dust. Because of the number of variables involved, this pathway is very difficult to model effectively. Recognizing the need minimize cross-contamination of residential and parkland from industrial sites, and the fact that an industrial guideline of 1000 ppm has been in place for several

years, it is recommended that the commercial/industrial decommissioning guideline for lead remain unchanged from its present value of 1000 ppm. This will also help to ensure that the quality of industrial soils is within an acceptable range of residential soils.

Special Considerations - Play Areas

Community or commercial play areas by their nature, attract large numbers of children. Vigorous play activities of the type normally encountered in these areas can result in increased soil ingestion which in turn increases the risk of exposure to lead. For this reason, special consideration should be given to ensuring that the lead levels in covering soil used for play areas such as sand lots, baseball diamonds, sand boxes *et cetera* is limited to the greatest extent possible. For special situations such as these, soil quality consistent with rural background soil should be used wherever possible.

3.1.4 Levels of Lead in Ontario Soils

The typical background levels of lead in Ontario soils is an important consideration when deriving new soil standards. In 1991, the MOEE began an extensive survey in the province to define typical ranges for different soil contaminants. The results of the survey are contained in the report, *The Ontario Typical Range of Chemical Parameters in Soil, Vegetation, Moss Bags and Snow or OTRs* (MOEE, 1992 Draft Report). The OTR_{98} value defines the upper limit of the concentrations found for 98% of the soil samples in that land use category. To date, OTRs have been developed for both urban and rural parkland soils removed from industrial sources of lead. OTRs for other land uses are being developed, including urban residential (both "old" and "new"), rural residential, and commercial/industrial sites.

For lead, the OTR_{98} for urban parkland is 98 ppm while the OTR_{98} for rural parkland is 45 ppm (MOEE, 1992 Draft Report). This means that 98% of all samples taken from urban and rural parkland are expected to have lead concentrations less than or equal to 98 ppm and 45 ppm, respectively. It should be noted that the OTR_{98} for urban parkland settings define lead concentrations at sites removed from buildings, roads or industrial activities.

OTRs are not yet available for urban residential or urban industrial/commercial sites, but data from a previous MOEE survey suggest that lead concentrations typical of urban sites can greatly exceed 98 ppm.

Indeed the Upper Limit of Normal (ULN) for lead in urban residential soils was established at 500 ppm (MOEE, 1989). In a recent survey of 94 households in a downtown Toronto neighbourhood removed from a known industrial source of lead, 25% of the 293 samples were in excess of 500 ppm, while 80% were in excess of 200 ppm and 90% were in excess of 125 ppm (MOEE, unpublished). The elevated soil lead levels are thought to be due to the historical use of lead-based paint and to atmospheric deposition prior to the phase-out of leaded gasoline.

The lead levels in urban industrial soil have not been extensively investigated. However, it is reasonable to assume that the distribution of lead in urban industrial soils would be similar to urban residential soils, provided the industries do not use or process lead and are removed from other industries that do. The soil lead concentrations for these sites should lie in the range of 100-1000 ppm with a median in the range of 250-500 ppm.

For agricultural soils, the majority of sites have lead levels between 1 and 50 ppm (mean 14.1 ppm), a range which can be considered background (Frank et al. 1976). As discussed above, the Ontario Typical Range for rural parkland soil is considered to be 45 ppm. However, because of the use of lead arsenate pesticides, certain fruit orchards can have elevated levels of lead in the soil. A survey of a variety of fruit orchards in Ontario recorded mean soil lead level of 125 ppm with a range of 4.4 to 888 ppm (Frank et al. 1976).

3.1.5 Consideration of Technical Achievability and Cost

While the reduction or elimination of environmental exposure to potentially toxic compounds is a desirable goal, its realization may be difficult to achieve for technical or economic reasons. Therefore, prior to recommending revised soil clean-up guidelines for lead it is important to examine both the technical achievability and potential costs associated with meeting revised standards.

Technologies available to treat lead-contaminated soil are summarized in Table 5. Technologies that immobilize lead in the soil matrix do exist, but they are not generally used in Ontario and are not considered further. The technologies presented in Table 5 differ depending on the size of the remediation project. For relatively small sites, removal and replacement is the preferred approach and cost depends mainly on the tipping fees for disposal of the lead-contaminated soil at secured landfill sites. Typical costs are about $160 per metric tonne where one tonne is approximately equivalent to a 10 metre square patch of soil excavated to a depth of 1 cm.

For large soil remediation programs, soil washing technologies are often used. These have a 70 to 98% removal efficiency and can achieve a residual soil lead concentration of about 100 to 200 ppm. Although the actual processing costs are modest, the technology is capital intensive, with a typical plant costing between $5 to $10 million. For this reason, soil washing is generally restricted to large scale remediation projects where several contaminants are removed at once.

Table 5 Soil Remediation Technologies for Lead[1]

Technology	Cost per tonne	Removal Efficiency	Comments
Soil removal	$150-430	meets background soil concentration; can be coupled with soil re-placement	contaminated soil disposed at landfill; costs are dependent on tipping fees
Soil washing[2]	$55-130	heavy metals 70% (to <200 ppm) lead 76%	best suited for sand and gravel; fine soils difficult to treat
Soil washing with chem-ical treatment and or EDTA chelation[2]	$55-130	heavy metals 67% (to 75-125 ppm) lead 75% (to 25 ppm) with EDTA treatment 94-97%	chemical augmentation can increase the efficiency of soil washing; EDTA soil washing demonstrated at pilot scale only
Electro-Reclamation[2]	$100-450	unknown	-

1. Sources: Remediation Technologies for Contaminated Soils, October 1992 MOEE
Identification of Potential Health Concerns of Soil Remediation Techniques, November 1991, City of Toronto
Contaminated Soil Treatment Technologies, 1991, Consultant's Report Prepared for Health and Welfare Canada by Intera.
2. Excludes costs associated with excavation and soil handling.

The costs associated with a revised soil clean-up guideline for lead will depend primarily on the number of sites requiring decommissioning and/or clean-up, as well as the additional cost needed to bring the soil lead levels down to the new standards. While decommissioning guidelines should not be considered values which when exceeded would trigger remedial action, it is illustrative to examine the potential costs associated with the clean-up of urban residential sites. In the City of Toronto, there are approximately 100,000 single detached

and semi-detached residences (City of Toronto Planning Department, personal communication, 1993). As illustrated in the preceding section, it can be assumed that due to historical uses of lead, approximately 80% of these residences have soil lead levels in excess of 200 ppm. Applying a clean-up cost of $10,000 per household (similar to that recorded during the South Riverdale Soil Replacement Project) the remediation cost for the City of Toronto alone would be in excess of $800 million. Applying these figures to other cities in the province with similar soil lead profiles, would result in a figure many times this amount. Based on cost approximations such as these, it is clear that approaches other than soil replacement and remediation should be considered when addressing large areas affected by elevated soil lead concentrations.

Soil clean-up guidelines are generally applied in the context of the Ministry's Decommissioning Policy (MOEE, 1989). This policy applies when land is rezoned, (i.e. from industrial/commercial to residential), or upon the decommissioning or the mothballing of industrial sites, and in the clean-up of spills. The costs associated with revising the soil clean-up guidelines for lead are difficult to estimate. Costs are dependent on the number of sites undergoing decommissioning or clean-up in the province; the amount of soil requiring remediation; and the incremental cost of meeting a revised guideline. One approach which can be used to estimate the cost is to examine the number of additional sites which would be affected by revising the lead guideline.

If it is assumed that the soil lead distribution for industrial/commercial sites which do not process lead-containing material is similar to urban residential soil, then approximately 25% of sites would exceed the current guideline of 500 ppm for medium and fine textured soil, 40% would exceed the current guideline of 375 ppm for coarse textured soil, 80% would exceed a value of 200 ppm and over 90% would exceed 125 ppm. Revising the guideline from 375 to 200 ppm would result in an approximate doubling in the number of sites requiring some level of remediation for lead. In the City of Toronto over the past five years, approximately 30 commercial/industrial sites were rezoned to residential land use. There were an additional 25 sites where land use was reclassified to residential (City of Toronto, personal communication). Employing the assumptions described above, a revised soil clean-up criteria of 200 ppm would mean that over the period of 5 years an additional 20 sites have would required some additional remedial action to address lead contamination. It should be noted that this can be considered an overestimate since it does not take into account remedial activity undertaken to address other contaminants. It should also be noted that for the majority of sites, most

of the exceedances will be limited to the surface soil and thus the actual amount of soil requiring remediation might be quite modest.

An alternate approach to obtaining potential cost information is to examine the additional costs which would be incurred at single large-scale remediation project. Ataratiri was a joint proposal by the City of Toronto and the Province of Ontario to redevelop a 32 hectare industrial site located east of the downtown core into a residential community. Approximately 50% of the soil at the site was determined to require some level of remediation which was estimated to cost $160 million (City of Toronto, 1991). Sampling data indicated that approximately 16% of the 767 samples tested for lead exceeded the residential clean up criterion of 375 ppm (mean 230 ppm; range, non-detect to 14,000 ppm). Revising the residential lead guideline from 375 to 200 ppm or 125 ppm would increase the number of samples exceeding a residential guideline to approximately 19% and 31% respectively. (The discrepancy between the percentage of samples in exceedance in this soil survey and that discussed above is attributed to the fact that the sampling at Ataratiri included subsurface soil taken at depths of up to 6 metres. Generally, lead contamination resulting from airborne deposition is restricted to surface soils). Assuming the clean-up costs are directly related to the number of samples exceeding the clean-up criteria for lead, means that a revised clean-up criteria of 200 ppm would increase the amount of soil requiring remediation and thus the costs by approximately 20%. A clean-up criteria of 125 ppm would result in an approximate doubling of the projected remediation cost at the site. It should be noted that these costs can be considered overestimates since they assume that the excess lead levels are driving the clean-up. For complex projects like Ataratiri, where many contaminants present simultaneously, the contaminant(s) of greatest concern generally drive the clean-up process.

3.1.6 Other Considerations

There is a certain degree of uncertainty associated with the derivation of a revised soil clean-up guideline for lead. Beyond the lack of certainty in understanding the socio-economic impact of a revised soil guideline for lead, there is uncertainty in estimating the level of risk and consequently the degree of benefit which might be anticipated from a revised soil clean-up criteria for lead. Much of the uncertainty associated with the latter derives from the complex relationship between blood lead levels and environmental sources of lead. Blood lead levels can be influenced by a number of confounding factors including behaviour, lifestyle, and socio-economic status.

The South Riverdale Soil Replacement Program provides a good example of the potential impact that reduced soil lead levels might have on children's blood lead levels. The Toronto Department of Public Health began surveying blood lead levels of children living in the South Riverdale neighbourhood of Toronto in 1984. This area is in close proximity to a secondary lead smelter and soil surveys indicated that the lead levels at several sites were in excess of 1000 ppm. The 1984 blood lead survey demonstrated that children living in the neighbourhood had significantly higher blood lead levels than average. The elevated blood lead levels were in part attributed to the immediate vicinity of an industrial source of lead, traffic density, soil lead levels and socio-economic status.

As a result of the elevated blood lead levels of children living in the area, the Ministry of Environment undertook a $10 million soil removal and replacement program in 1987 and 1988 for designated areas within the community. Soil containing greater than 500 ppm lead on 974 residential properties and public boulevards was removed to a depth of 30 cm and replaced with clean top soil (<60 ppm lead). In addition, affected houses were professionally cleaned to remove indoor house dust which may have contained elevated levels of lead. Blood lead survey data collected since 1984 indicates that the blood lead levels of children within the community have declined significantly. Since completion of the soil replacement program in 1988, follow-up blood lead surveys were conducted in 1990 and again in 1992. Although results from the 1990 survey confirm that the blood lead levels of children in the area have continued to decline, the decrease since 1988 cannot be attributed to the soil replacement program since a similar decrease was observed in the general Ontario population over the same time period. Results from the 1992 survey have not yet been released, but should provide a clearer indication of the relative contribution the soil replacement program has had on blood lead levels in the community.

Similar difficulties in predicting the effects of soil lead levels on blood lead levels have been reported in other jurisdictions. Some studies fail to find a correlation, while others do report a positive correlation ranging from a 0.6 to a 7.0 µg/dL rise in blood lead for every 1000 ppm of soil lead (MOEE, 1993). The large range may be explained by the influence of other factors, such as the extent of vegetation cover, lifestyle, socio-economic status and other sources of lead exposure. Notwithstanding these observations, it is felt that because soil remains a continual source of lead exposure, its contribution to elevated blood lead levels is significant.

3.1.7 Discussion and Recommendations

The recommendation for revised soil clean-up guidelines protective of human health must weigh the anticipated benefit against other practical considerations. It will, of course, involve a level of professional judgment, because there are many environmental sources of lead, and because there is some uncertainty in linking elevated blood lead levels to a single source, such as soil lead. Nevertheless, the recent assessments of adverse health effects resulting from low levels of lead exposure strongly support lowering the residential/parkland decommissioning guideline from its present value of 500 ppm (fine and medium textured soil).

Recommendation 1:

> The revised residential/parkland soil guideline be set at 200 ppm, a value which, based on exposure modelling, will protect the health of children between the ages of six months to four years. As children are the most sensitive receptors for lead, this level will also protect the general population. The revised guideline is technically feasible because certain soil remediation techniques can achieve levels of 200 ppm.

Recommendation 2:

> The exposure to lead through the consumption of backyard vegetables grown in lead contaminated soil should not be a driving factor for a revised residential/parkland guideline. Although such food can be a source of lead exposure, it is felt that the degree of uncertainty in estimating the amount of home-grown vegetables eaten by Ontario children aged 0.5 to 4 years in addition to the overall uncertainty in predicting the influence of soil lead on blood lead levels is unacceptable when compared to the potential increase in costs associated with a lower residential soil clean-up guideline. It is recommended that both of these issues be the subject of further research.

Recommendation 3:

> The industrial/commercial decommissioning soil guideline for lead should remain at its present value of 1000 ppm.

Recommendation 4:

The agricultural soil criterion for lead should be reduced from its present value of 500 ppm to 60 ppm to protect food crops from lead contamination. The revised value of 60 ppm is close to what is considered background for agricultural soils and is consistent with the recommended maximal soil lead concentration under the *Guidelines for the Utilization of Sewage Sludge on Agricultural Lands.* (see Preface)

Recommendation 5:

The current distinction between coarse and fine-textured soils should be discontinued for lead. This is because the revised lead guidelines are based on protection of human health and the affect of soil texture on the availability of lead to humans is not well enough understood for the development of quantitative relationships. The Ministry of Environment and Energy is currently sponsoring research to better understand this issue.

Recommendation 6:

Special consideration should be given to ensuring that the levels of lead in covering soil used for community or commercial play areas, like sand lots, baseball diamonds and sand boxes, is limited to the greatest extent possible. Soil quality consistent with rural background soil should be used for these areas wherever possible.

Recommendation 7:

The proposed soil guidelines, (residential/parkland, industrial/commercial, agricultural) be reviewed as new information becomes available and it is deemed necessary to reassess the basis of these guidelines.

The background concentration of lead in some urban environments are expected to exceed the revised residential/parkland guideline of 200 ppm because of the many historical uses of lead. It should be stressed, however, that this does not mean that

these sites now pose an unacceptable risk to human health. The health risk to an individual depends on the degree of exposure to the lead-contaminated soil. Means by which exposure to soil lead can be reduced are discussed in Section 5.0.

3.2 Derivation of an Ontario Drinking Water Objective for Lead

3.2.1 Application of Drinking Water Objectives

The *Ontario Water Resources Act* is the legislation which governs municipal drinking water systems in Ontario. Under this legislation, a Certificate of Approval is required prior to construction of a new water works or alteration of an existing works. As a condition of the Certificate of Approval, the water works must be able to supply drinking water which meets the requirements of the Ontario Drinking Water Objectives (OMOE, 1983).

While the responsibility for ensuring that drinking water is safe for consumption rests with the supplier, regional and district staff of the Ministry co-operate with the local Medical Officers of Health to control potential health problems associated with drinking water supplies. Under the *Health Promotion and Protection Act*, the local Medical Officer of Health has the authority to determine whether water is safe for human consumption. The principle guidelines used for making that determination are the Ontario Drinking Water Objectives (ODWOs).

In setting ODWOs, Ontario generally adopts Canadian Drinking Water Guidelines developed by the Federal-Provincial Subcommittee on Drinking Water. This committee was established in 1986 as a standing committee with membership from each province, territory and the federal government.

While Ontario generally adopts the Canadian Drinking Water Guidelines as ODWOs, the province has set certain drinking water objectives independent of the Federal-Provincial subcommittee. These include health-based criteria for nitroso-dimethylamine (NDMA), polychlorinated biphenyls (PCBs) and dioxin as well as aesthetic criteria for colour, dissolved organic carbon (DOC), sulphate and methane.

The current drinking water objective for lead of 10 µg/L (parts per billion), was established nationally and provincially in 1991. This criteria was proposed in 1989 after an extensive review of the adverse health risks resulting from exposure to low levels of lead and was guided by considerations of practicality. Prior to 1991, the maximum allowable concentration of lead in drinking water was 50 µg/L.

3.2.2 Regulatory Comparison with Other Jurisdictions

Table 6 International Lead Regulations for Drinking Water

AGENCY	LIMIT	COMMENTS
Canada	10 µg/L (flushed)	Maximum allowable concentration based on human health effects (guidelines)
USA: USEPA	15 µg/L (standing)	Action level Regulated under the *Safe Drinking Water Act*, 1986
	0 µg/L	Maximum contaminant level goal
	20 µg/L	Recommended maximum contaminant level based on a long-term health advisory
New York	50 µg/L	Ambient water quality standards, regulations for drinking water supplies based on human health effects
	25 µg/L	Ground water quality standards, regulations for ground water
Germany	40 µg/L	Maximum permissible concentration
WHO	50 µg/L	Based on human health effects

3.2.3 Derivation of a Health-based Criteria

As discussed in Section 3.1 dealing with soil, a recommended health-based criteria for lead in drinking water is derived by applying an allocation factor and consumption rate of water to the intake of concern for lead. This derivation is described by the following equation:

$$\text{Drinking Water Guideline} = \frac{IOC_{pop} \times AF \times BW}{\text{Consumption Rate}} \qquad \textbf{[Equation 3]}$$

$$= \frac{1.85\ \mu g/kg/day \times .12 \times 13\ kg}{0.6\ L/day}$$

$$= 4.8\ \mu g/L$$

Where:

IOC_{pop} = intake of concern or 1.85 µg/kg/day

AF = allocation factor for drinking water or 12%

BW = average body weight of a 0.5 to 4 year old child or 13 kg (average child 0.5-4 years of age)

CR = consumption rate or 0.6 L/day

Incorporating these values into this equation derives a desired health-based drinking water objective of approximately 5 µg/L.

3.2.4 Levels and Trends in Ontario

The most comprehensive program in Canada for the assessment of drinking water quality is the Drinking Water Surveillance Program (DWSP) administered by the Ministry's Water Resources Branch. DWSP was established in 1986 as a means of obtaining accurate and reliable data to assess drinking water quality and the efficiency of the water treatment process. Water quality is assessed by measuring up to 180 parameters on water samples representative of the treatment process. This includes samples taken from raw water, treated water, and water taken from two households in the distribution system. Over 100 drinking water plants and distribution systems are assessed under this program. While this represents only 25% of the drinking water systems in Ontario, it covers 85% of Ontario's population served by municipal drinking water.

A summary of the DWSP data for lead analyses collected between 1987 and March 1993 is presented in Table 7. From this data it is clear that, with very few exceptions, raw and treated water does not contribute significantly to the levels of lead in drinking water. Rather, the majority of lead is introduced once water enters the distribution system. This is best illustrated by comparing lead levels in samples taken from water left standing overnight in pipes to those taken after flushing the pipes for several minutes. Approximately 25% of standing samples exceeded 5 µg/L whereas only 1.7% of the flushed samples exceeded the same limit. It should be noted that ODWOs apply to free flowing water delivered to the consumer and are best represented by flushed samples.

Table 7 Summary of DWSP Data for Lead Analyses (1987-1993)

Sample Location	Number of Analyses	Number of samples >10 µg/L	Number of samples >5 µg/L
Raw Water	4,123	12	31
Treated Water	4,522	5	16
Distributed Water			
Standing (overnight)	4,570	515	1119
Flushed (5 minutes)	4,728	22	81

The presence of lead in drinking water results primarily from the corrosion of materials containing lead located throughout the distribution system including lead plumbing materials used within the home. The potential sources of lead in drinking water include lead based fittings; lead service lines and interior household pipes; lead solders and fluxes used to connect copper pipes; and alloys containing lead, including some faucets made of brass or bronze. Until recently, lead solder and fluxes containing up to 50% lead were used widely to connect copper pipes throughout the province. An amendment to the Ontario Plumbing Code introduced in 1989, specifies that solder used in potable water systems contain not more than 0.2% lead.

The amount of lead in drinking water depends to a large degree on the corrosiveness of the water. By its nature all water is corrosive to metal plumbing material to some extent. In addition to the corrosiveness of water, other factors which affect the amount of lead in drinking water are the number and age of lead soldered joints, quality of workmanship, the surface area and the length of time water is left in contact with lead-bearing material (Federal Register, Vol 56 #110: 26460-26564).

3.2.5 Control Technologies

Since the majority of lead contamination is introduced by the distribution system including the pipes used in private dwellings, the control of lead differs significantly from other drinking water contaminants where source water is treated to remove the contaminant. There are three main strategies which can be taken to reduce the lead content of drinking water delivered to the consumer's tap. These include 1) flushing the lines to remove standing water 2) replacement of lead-containing service lines

and fittings and 3) reducing the corrosivity of the water. These strategies are discussed below.

Flushing

As shown in Table 7 and Appendix A (Table A.1), flushing lines of standing water can have a dramatic affect on the levels of lead present in drinking water. While there are many instances where the level of lead in standing water is in excess of 10 μg/L, flushed samples generally have lead levels below 5 μg/L. To minimize lead contamination, it is generally recommended that water used for consumption be drawn from taps that are run for several minutes, or until the water is thoroughly cold. This ensures that water which may have been left standing in household pipes overnight is not used for consumption. While this is appropriate for single family homes, it may not be practical for larger multi-unit residences where the consumer's tap may be a considerable distance from the water main. In these situations, however, there is often a pattern of continuous use of water throughout the day which helps to keep the pipes free of standing water.

One concern often expressed is that the recommendation for line flushing contradicts good water conservation practices. To avoid wastage, water used for consumption should be drawn from taps only after other non-consumption uses such as showering, bathing, washing dishes and clothes have occurred. In addition, to reduce the frequency of collecting drinking water, flushed water can be stored in the refrigerator in pitchers or bottles.

Replacement of Service Lines

Lead service lines and pipes were at one time used extensively to connect private dwellings to the main water line. While information pertaining to the number of service lines in use in Ontario is not available, recent estimates suggest that there are approximately 10 million lead service connectors still in use in the United States (AWMA, 1989 and 1990 cited in Federal Register). The United States Environmental Protection Agency has estimated that the cost to replace lead service lines ranges from $900 US to $1800 US per line depending on local circumstances and replacement method (EPA, 1991 cited in Federal Register). Lead service lines in Ontario are likely present in older urban neighbourhoods and while there is no formal program to replace these lines, they are generally replaced by municipalities during the normal course of repair work and updating.

Corrosion Control

One means by which individual water treatment plants can affect lead levels delivered at consumers' taps is by controlling the corrosiveness of water. This can be done by increasing the pH of the water through the addition of lime, caustic soda, sodium carbonate or sodium bicarbonate during the treatment process. However, changes in pH affect other essential treatment processes such as disinfection and coagulation, a process used to remove suspended particulate matter. Increasing the pH, may result in increased levels of trihalomethanes, by-products of the disinfection process. As such, careful consideration must be given to the effects that changes in pH will have on the efficiency of the water treatment process. In addition, changes in pH may increase the degree of corrosiveness towards other metals used throughout the distribution system and as a result, may affect the ultimate quality of treated water delivered to the consumer. Therefore, prior to implementing a program that would control corrosiveness by increasing the pH of water the impact of these changes will need to be assessed on a plant-by-plant basis.

3.2.6 The Cost of Lead Control Programs

To understand the costs associated with revising the ODWO for lead it is necessary to identify those water distribution systems where corrective action may need to be taken to control lead levels. As discussed in previous sections, data obtained from DWSP was examined to determine those areas of the province where the corrosivity of the water may be a contributing factor towards the levels of lead detected in drinking water. Results comparing the annual average for treated, flushed and standing samples for all plants analyzed is provided in Appendix A. A large difference between flushed and standing samples is indicative of situations where the corrosiveness of the water is a contributing factor to increased levels of lead. Of 128 distribution systems tested, 48 recorded an annual average for standing samples in excess of 5 µg/L for two or more consecutive years. No distribution systems recorded annual averages for flushed samples in excess of 5 µg/L for two consecutive years.

While most samples taken from flushed pipes report lead levels below 5 µg/L, the data needs to be interpreted with some caution since DWSP samples only at two homes on each distribution system. As a result, DWSP, while indicative of trends across the province, may not be representative of each distribution system. Because lead is introduced by plumbing systems within residences and can be affected by the length of pipes and the number and quality of soldered joints, there can be

As a result of these concerns, the MOEE recommended regular flushing and monitoring programs for drinking water fountains in schools in the Province. The Ministry of Education and Training has recommended to school boards that they regularly flush drinking fountains and monitor drinking water for lead in their schools.

3.2.8 Discussion and Recommendations

Lead differs from other drinking water contaminants since the majority of lead is introduced by the distribution systems rather than the source water. Thus, the traditional approach of treating source water to remove contaminants is considered to have a marginal effect in controlling lead levels at the consumers tap. In addition, the observation that standing water contains significantly higher lead levels than flushed samples, means the application of ODWO to flushed samples ignores a significant public health issue. The recommendation for a ODWO for lead takes these issues into consideration while recognizing that the available database on lead levels in drinking water is limited to 25% of the water supply systems in the province and was not designed to provide water quality data for distribution systems.

Recommendation 1:

> The Ontario Drinking Water Objective remain unchanged from its present value of 10 µg/L. The rationale for this recommendation is that DWSP data, while indicative of trends across the province, is not representative of homes on a particular distribution system. As a result, there may be areas of the province where the levels of lead in drinking water exceed a desirable health-based criteria. The potential cost for corrosion control to address these areas and the impact on other key treatment processes need to be carefully evaluated prior to recommending revising the ODWO for lead. While the ODWO for lead is higher than the desirable health-based criteria, continuous exposure to this level represents only an increase in total lead exposure of only 11% over a limit defined by the IOC_{pop}.

Recommendation 2:

> Municipalities, in cooperation with the MOEE, undertake a comprehensive drinking water survey which is representative of each distribution system for lead levels in both flushed and standing samples.

considerable variability from home to home. This makes it very difficult to assess the concentrations of lead delivered to each consumer's tap.

Recognizing this limitation, cost data was developed for those locations identified in Appendix A where some level of corrosion control may be necessary to control lead levels (Appendix B). Costs were estimated for the addition of a lime softening step during the treatment process. Costs for coagulation/filtration are also included on the assumption that a drinking water plant would be required to construct a new treatment unit to compensate for the affect that changing pH may have on the efficiency of coagulation. In many cases, especially for large systems this may not be necessary. The annual costs are based on a 20 year amortization period at 8% interest rate.

Based on the data provided in Appendix B, total capital costs for the implementation of corrosion control programs could range as high as $1.5 billion for the province. Depending on the size of the municipality this would be reflected in annual increases to the householder ranging from $5.94 to $2,394. The higher projected costs are generally for those municipal water systems which service a small number of households. Costs to replace lead lines in the province have not been included in these estimates since information is not available. However, considering that some municipalities may find it necessary to replace lead lines and service connections in addition to corrosion control, the costs may be greater than those quoted.

3.2.7 Schools as a Special Case

The level of lead in drinking water is of particular concern in schools since the population exposed, especially for elementary schools, is considered among the most sensitive to lead exposure. In addition, the fact that schools have a large number of pipes and plumbing fixtures which are not normally flushed by routine domestic activities, means that drinking water can be left standing in pipes for considerable periods of time. Thus lead levels in water obtained from drinking fountains is a potential concern.

In response to this concern, the Ontario Ministry of Education and Training, in consultation with the Ministry of the Environment and Energy, initiated a survey of lead in drinking water in 1989 which covered approximately 3,800 elementary schools and 21 secondary schools in the province. Results showed that the average lead level in standing water collected from school fountains was below 25 µg/L, while the average lead level after a five minute flushing was below 5 µg/L. These results exemplify the necessity and value of flushing drinking fountains first thing every morning.

The results will be used to assess the corrosivity of the water. Where the lead concentration in standing water greatly exceeds the lead concentration in the flushed water, municipalities implement, in cooperation with the appropriate public health agencies, education programs for those areas of high risk. Where results indicate that greater than 10% of flushed samples are in excess of 10 µg/L, municipalities implement appropriate measures to control the corrosiveness of water.

Recommendation 3:

For individual households which have a concern about the presence of lead in drinking water, it is recommended that water used for consumption be drawn from taps which have been flushed of standing water. If implemented properly, the recommendation for flushing need not be inconsistent with water conservation programs. Section 5 provides further details on the best ways for implementing home flushing programs.

Recommendation 4:

School Boards in Ontario maintain a consistent and regular flushing and monitoring program within their schools to reduce children's potential exposure to lead.

Recommendation 5:

The Ontario Drinking Water Objective for lead be reviewed as new information becomes available and it is deemed necessary to reassess the basis of this guideline.

3.3 Derivation of Ambient Air Quality Standards

3.3.1 Application of Current MOEE Standards

As part of its air management program, MOEE utilizes ambient air quality criteria (AAQC) and point of impingement standards established under Regulations 337 and 346 (formerly Regulations 296 and 308). For lead, the appropriate criteria specified by these regulations is summarized in Table 8.

Table 8 Current Air Quality Standards and Guidelines for Lead

Air Quality Standard or Guideline	Level ($\mu g/m^3$)	Statutory Authority	Comments
1/2 hour point of impingement standard	10	Environmental Protection Act, O.Reg. 346, Schedule 1	maximum concentration for a contaminant at a point of impingement from a source other than a motor vehicle
24 hour ambient air quality criterion	5	Environmental Protection Act, O. Reg. 337	average over a 24 hour period
30 day ambient air quality criterion	3		arithmetic mean over a 30-day period
30 day ambient air quality criterion	2		geometric mean over a 30-day period

Point of impingement standards (Regulation 346, Schedule 1), are used to approve new sources of emissions as part of the Ministry's certificate of approval process. This regulation specifies that the maximal 1/2 hour concentration of contaminant impacting the borderline of the property cannot exceed the standard specified in Schedule 1 of the Regulation. The determination of 1/2 hour maximal point of impingement concentration by a particular facility is based on modelling using known or predicted emission rates for the contaminant of concern. Standards

specified under Regulation 346 are the main enforcement tools used by the Ministry when dealing with air emissions.

Ambient air quality criteria specified under Regulation 337 represent desirable air quality criteria. AAQCs include a variety of averaging times ranging from single samples to annual averages. AAQCs are used for a number of purposes including, the assessment of general air quality, environmental assessments, and the evaluation of the Ministry's air management programs. The relationship between the 1/2 hour point of impingement standard in Regulation 346, and the 24 hour and 30 day AAQCs in Regulation 337 is empirically based. Generally, 1/2 hour point of impingement standards are set such that 24 hour and 30 day AAQCs are not exceeded.

The purpose of this section is to derive revised air standards and guidelines for lead in Regulation 346 and 337. These will be derived taking into consideration risk to human health, technical feasibility as well as socio-economic impacts.

3.3.2 Regulatory Comparison with Other Jurisdictions

Lead in air is regulated in many jurisdictions. Table 9 provides a summary some of the national and international air lead regulations.

Table 9 International Lead Regulations: Air

AGENCY	LIMIT	COMMENTS
CANADIAN PROVINCES		
Manitoba	5 μg/m³	24 hour exposure period guideline
Quebec	0-2 μg/m³	annual exposure period guideline
Newfoundland	5 μg/m³	24 hour exposure period guideline
	2 μg/m³	30 day exposure period guideline
Montreal Urban Community	10 μg/m³	1 hour exposure period guideline
	5 μg/m³	8 hour exposure period guideline
British Columbia		
Ambient air control objectives (1979)	1-2.5 μg/m³	an objective based on ecological, health, technological and economic considerations
Ambient air quality guidelines	4 μg/m³	24 hour maximum desirable level (guideline) based on ecological, health, technological and economic considerations
	4 μg/m³	24 hour maximum acceptable level (guideline)
	6 μg/m³	24 hour maximum tolerable level (guideline)
UNITED STATES		
OAQPS: national ambient air quality standards	1.5 μg/m³	maximum arithmetic mean over calendar quarter based on human health effects (standard)
State Acceptable Ambient Air Limits		
California	1.5 μg/m³	30 day arithmetic mean (standard)
Connecticut	3.0 μg/m³	8-hour average (guideline)
Kansas	0.357 μg/m³	1-year average (guideline)
Massachusetts	0.140 μg/m³ 0.070 μg/m³	24-hour average (guideline) annual average (guideline)
North Dakota	0.0015 mg/m³	8-hour average (guideline)
Nevada	0.004 mg/m³	8-hour average (guideline)
Pennsylvania/Philadelphia	1.50 μg/m³	annual and 1-year average (guideline)
Virginia	2.50 μg/m³	24-hour average (guideline)
Vermont	1.5 μg/m³	3-month average (guideline)
European Community	2 μg/m³	maximum limit
Germany	0.1 mg/m³	8 hr TWA
WHO	30-60 μg/m³	maximum limit

3.3.3 Derivation of Health-based Criteria

The most sensitive receptor for exposure to lead in air is a child aged 0.5 to four years, however the multimedia exposure assessment has allocated less than one percent of a child's lead intake to this route of exposure (Table 2). In deriving the revised standards, the intermedia transfer of lead was not considered, but the impact of this potential transfer is discussed in Section 3.3.4.

As discussed in Sections 3.1 and 3.2, a recommended health-based criteria for lead in air is derived by applying an allocation factor (1%) and contact rate of air (5 m^3/day) to the intake of concern for lead. This derivation is described by the following equation

$$\text{Standard/Guideline} = \frac{IOC_{pop} \times AF \times BW}{CR_{air}} \qquad \textbf{[Equation 4]}$$

$$= \frac{1.85\ \mu g/kg/day \times .01 \times 13\ kg}{5\ m^3/day}$$

$$= 0.048\ \mu g/m^3$$

where:

IOC_{pop} = intake level of concern or 1.85 µg/kg/day
AF = allocation factor for air or 1%
BW = average body weight of a 0.5 to 4 year old child or 13 kg
CR = average daily contact rate with ambient air

Based on the above derivation, a desirable health-based average ambient air concentration for lead is 0.05 µg/m^3.

3.3.4 Considerations of the Impact of Air Deposition on Soil Lead Levels

As discussed in Section 2.0, inhalation is thought to represent less than 1% of a child's total exposure to lead. Therefore, changes in the ambient air concentration will have little affect on overall exposure. However, considering that soil represents the major route of exposure, and that the majority of lead in urban soil is the result of airborne deposition, it is important to evaluate the potential impact the ambient air standards will have on soil lead levels.

The relationship between lead levels in air and the corresponding levels in soil is complex. The relationship is affected by weather patterns, deposition rates, soil type and particle size. For a simple estimate, under ideal conditions, the impact on soil can be estimated using the deposition rate of a lead-bearing particle. For this derivation it is assumed that lead-bearing particles are 20 µm (equivalent to a medium silt). The deposition velocity of a 20 µm particle is approximately 2.5 cm/sec or 0.025 m/sec. Using an ambient air lead level of 0.05 µg/m³ a rate of airborne deposition may be estimated using the following equation:

Deposition rate = particle velocity x $[Pb]_{air}$ x time **[Equation 5]**

$$= 0.025 \text{ m/sec} \times 0.05\ \mu g/m^3 \times 3.1536 \times 10^7 \text{ sec/yr}$$

$$= 3.942 \times 10^4\ \mu g/m^2/yr$$

If the mixing depth of soil is assumed to be 15 cm and the soil density is assumed to be 1.0 g/cc, then the deposition on 1 square metre would be distributed throughout 150 kilograms of soil. The annual rate of soil contamination would be as follows:

Annual rate of soil contamination = deposition rate/weight of contaminated soil **[Equation 6]**

$$= \frac{3.942 \times 10^4\ \mu g/m^2/yr}{150 \text{ kg}}$$

$$= 0.26 \text{ mg Pb/kg soil/yr}$$

This means that if the concentration of lead in ambient air were 0.05 µg/m³, in 100 years, an additional 26 ppm of lead would have been added to the soil as a result of aerial deposition. Under the current 30 day ambient air quality guideline of 2 µg/m³, aerial deposition would result in a soil lead level of approximately 520 ppm over a 50 year period.

3.3.5 Ambient Air Lead Levels in Ontario

The Ministry maintains a province-wide ambient air monitoring network which measures the concentrations of various air contaminants throughout Ontario. Ministry data show that as of 1980, the average lead levels in ambient air dropped from 0.30 to 0.01 µg/m³. The latter level is the analytical detection limit for lead

(Figure 1). Since monitoring is concentrated in areas with heavy traffic or near industrial sources of lead, the air concentrations of lead elsewhere in Ontario have declined to levels lower than 0.01 μg/m^3. This large decrease has been attributed to the phase-out of leaded gasoline.

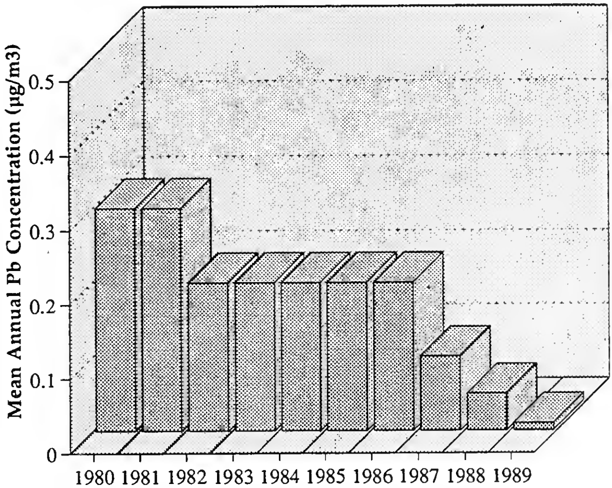


Figure 1: Ambient Air Lead Levels in Ontario, 1980-1989 (Source: MOEE, 1991)

Current sources of lead emissions in Ontario are provided in Table 10. While primary lead smelters account for the largest volumes of lead emitted into the environment, exceedances of the Ministry's 24-hour ambient air quality criterion have only been recorded in the vicinity of Ontario's two existing secondary lead smelters[1] (only one of these secondary lead smelters is currently operational). Based on an analysis of air monitoring data collected over the past decade, secondary lead smelters will be the only industries which are anticipated to be affected by revised air standards for lead. Although the total amount of lead emitted by these industries is relatively small (5.9 of 324 tonnes), the fact that they emit relatively high concentrations of lead makes their impact on human exposure highly significant.

[1]A few exceedances have been observed near the demolition sites of old buildings. This is likely dust to the mobilization of dust from lead-based paints.

Table 10 Sources of Lead Emissions into the Ontario Environment

INDUSTRY	EMISSIONS (tonnes/year)
Non-Ferrous Smelters and Refiners	
Primary Smelters	211
Secondary Smelters	**5.9**
Automotive Industry	
Wet-cell Automotive Battery Production	51.1
Petrochemical Products Industry	
Metallic Additives	52.4
Waste Disposal Industry	
Semi-suspension Incinerator	2.4
Multichamber Incinerator	0.03
Fluidized-bed Incinerator	0.10
Multihearth Incinerator	0.90
Commercial and Industrial Incinerator	0.04
TOTAL	**323.87**

Source: MOEE, 1990b

3.3.6 Consideration of Technical Achievability and Cost

Secondary lead smelters recycle waste lead primarily from spent lead-acid batteries. A model facility is able to recover up to 98% of the materials contained in a used automotive battery, including metallic lead, polypropylene from the battery casings and the sulphuric acid solution itself. The latter can be converted into detergent grade sodium sulphate. Recycling of lead-acid batteries can therefore benefit the environment by recovering resources and reducing the amount of solid waste sent to landfills. This is provided that reliable control technologies and good management practices are implemented to prevent the emission of lead and other harmful chemicals.

Two types of atmospheric emissions of lead are released by secondary lead smelters: stack and fugitive emissions. Stack emissions are those that are captured through engineering controls and are vented to the atmosphere through a central stack or

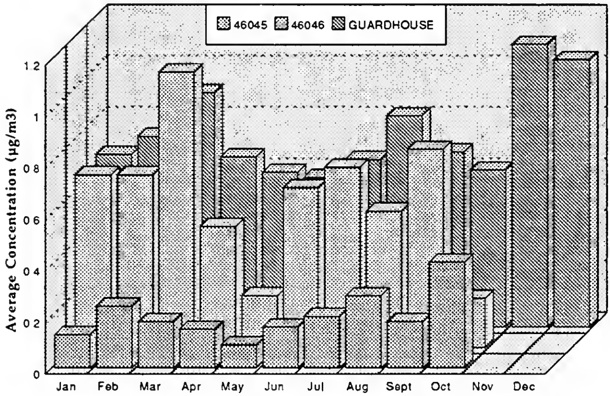
stacks. Because air flows through a managed system, the control of lead emissions is relatively easy and is achieved primarily through the use of baghouses (large vacuum filters). Provided that engineering controls are operating properly, the control of lead levels in stack emissions can be very effective. The best available technology (BAT) for controlling such emissions are fabric filter baghouses, which can achieve a performance efficiency of better than 11 mg/m^3 for particulate emissions (Environment Canada, unpublished consultants report, 1992).

Fugitive emissions generally occur through the generation and mobilization of lead-containing dust from materials handling and transport. Because these emissions are not generally captured by direct engineering controls, they represent the single biggest source of lead pollution from secondary lead smelters. Fugitive emissions can be controlled in several ways: by enclosing battery breaking operations; paving yard surfaces; using water to suppress dust formation; yard vacuuming; washing the tires of trucks leaving the facility; and changing the process design to minimize the need for materials handling (Environment Canada, unpublished consultants report, 1992).

Technical achievability is an important consideration in proposing revised air standards for lead. In many cases, emission standards can be defined based on the performance limits met by BAT or the best available technology economically achievable (BATEA). However, these performance limits alone cannot be used because fugitive emissions, the largest source of lead pollution, are difficult to assess and quantify. In order to obtain this information, the emission monitoring data and the controls used were examined at an operating secondary lead smelter in Ontario. This secondary lead smelter operated by Tonolli in Mississauga was selected for this analysis since it has maintained a consistent operating record with respect to the amount of lead processed, and has installed a number of systems to control lead emissions. These are listed in Table 11. In addition, Tonolli uses an automated spraying system to control yard dust (Legati, personal communication).

Three ambient air monitoring stations are located near the smelter, one maintained by Tonolli itself at the border of its property, the other two by the Ministry located further away from the facility. The three stations collect air monitoring data on a 24 hour basis and these are later combined to obtain monthly and yearly averages. Figure 2 shows the monthly averages obtained in 1992. The average for the monitoring station which recorded the highest lead levels is approximately 0.7 µg lead/m^3. These levels were recorded from the air monitoring station located at the border of the plant. In those months where the level of lead emissions are greater than 1 µg/m^3, the elevated levels can be attributed to several days where elevated lead levels were detected. These may have resulted for a number of reasons including plant upset, construction activities unrelated to operations at the facility, or

cold weather where it is impractical to implement yard spraying as a means of controlling dust mobilization.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
GUARDHOUSE	0.67	0.74	0.91	0.66	0.6	0.58	0.65	0.82	0.68	0.61	1.1	1.04
46046	0.67	0.67	1.07	0.47	0.2	0.62	0.7	0.53	0.77	0.19		
46045	0.13	0.24	0.18	0.15	0.09	0.16	0.2	0.28	0.18	0.41		

Month

Figure 2: Monthly Averages for Monitoring Stations Near Tonolli Canada, 1992

The analysis of this information suggests that the Tonolli smelter can currently achieve a monthly average of 0.7 $\mu g/m^3$ as a emission limit. If it is accepted that Tonolli employs BAT to address its lead emissions, then 0.7 $\mu g/m^3$ may be considered a BAT-derived air quality standard for lead. The costs associated with Tonolli achieving this emission limit are also included in Table 11.

Capital costs include engineering and design; purchase and installation of equipment, facilities or structures; and feasibility studies. Operating costs include energy requirements, materials, labour, and maintenance. Based on 1992 figures, capital costs are estimated to be \$5.6 million, and annual operating costs to be \$985,000 (Legati, personal communication). Available options to meet tighter standards include plant re-design to minimize materials handling; enclosure of the entire plant to capture all fugitive emissions; purchase of a buffer zone around the plant to dilute off-site migration; plant relocation to a less sensitive area; and, possibly, increased vigilance on behalf of workers at the plant.

Table 11 Emission Control Equipment for the Tonolli Secondary Lead Smelter

EQUIPMENT	CAPITAL COSTS	YEARLY OPERATING COSTS
Kettle baghouse	150,000	70,000
Paste building baghouse	200,000	60,000
Rotary furnace sanitary hood baghouse	150,000	60,000
Refinery roof baghouse	200,000	60,000
New electrically operated door(s) systems for entire facility to balance ventilation	50,000	10,000
Two vacuum sweepers	60,000	50,000
New paste storage building (including charge preparation)	750,000	10,000
Flue dust system	150,000	15,000
Truck tire washing facility	400,000	50,000
CX Phase I (including new wet battery breaking systems and re-vamping of building etc)*	3,500,000	600,000
TOTAL	5,610,000	985,000

Source: Legati, personal communication

If a technology based standard is to be recommended, it is important to demonstrate that such a standard is protective of human health and the environment. As discussed in Section 2.2, direct inhalation is considered to be a minor pathway of exposure to lead. Although this figure is based on an ambient air level of 0.05 $\mu g/m^3$ continuous exposure to 0.7 $\mu g/m^3$ would increase total lead exposure by only 14% (0.7/0.05 x 1%) over a limit defined by the IOC_{pop}.

The potential impact on soil as a result of air deposition can also be considered. Using the relationship derived in Section 3.3.4, a technology-based standard of 0.7 $\mu g/m^3$ would lead to an increase of approximately 185 ppm lead at the point of impact over a period of 50 years.

3.3.7 Derivation of a 24 Hour AAQC and 1/2 Hour Point of Impingement Standard for Lead

As discussed in section 3.3.1, the 1/2 hour point of impingement standard is derived such that the 24 hour and 30-day ambient AAQCs are not exceeded. Starting with a revised 30 day average guideline, it is therefore necessary to determine the appropriate conversion factors needed to derive a 24 hour average guideline and a 1/2 hour point of impingement standard.

The derivation of a conversion factor relating a 30 day average concentration to a 24 hour average is based on data collected from air monitoring stations affected by a point source of lead (see Appendix C for details of the derivation). The maximum 24 hour concentration for each station was compared to the long-term average. On the basis of this comparison, a factor of 3 is recommended to convert from a criterion based on a 30 day average to one based on a 24 hour average. The use of such a factor provides reasonable assurance that by meeting the 24 hour average guideline for lead, the 30 day average will not be exceeded.

Similarly, to convert from a 24 hour average to a 1/2 hour maximum, a conversion factor of 3 is also used. The derivation of this factor is similar to that described above, however, since lead concentrations are not measured for time periods less than 24 hours, data from surrogate compounds were used for this analysis (Appendix C).

Employing these factors yields the following proposed AAQCs and point of impingement standards for lead (Table 12).

Table 12 Proposed Air Quality Guidelines and Standards for Lead

Proposed Air Quality Standard and Guidelines	Level (μg/m3)	Statutory Authority
1/2 hour point of impingement standard	6	Environmental Protection Act, O. Reg. 346
24 hour average ambient air quality criterion	2	Environmental Protection Act, O. Reg. 337
30 day ambient air quality criterion (arithmetic average)	0.7	

3.3.8 Other Considerations

A significant source of uncertainty is understanding the impact that airborne deposition has on soil lead levels. The analysis presented in section 3.4.4 assumes an average particle size of 20 μm. This is because particles larger than this should be captured by the baghouses used to control lead emissions. However, considering the majority of lead emitted from secondary lead smelters is thought to result from fugitive emissions, the assumption of a 20 μm particle size may be inappropriate for this analysis. The particles released as a result of fugitive emissions may be larger in size therefore the deposition rate of airborne lead to soil can be greater than that calculated in section 3.3.4. Since soil represents the single largest source of lead exposure for children, a better understanding of the impact that airborne deposition has on soil lead levels is needed.

3.3.9 Discussion and Recommendations

Lead in air is the smallest contributor to a child's exposure relative to other sources. Although ambient air lead concentrations in Ontario have declined significantly in the past decade, the deposition of air lead to soil continues to be of concern, particularly near industrial point sources of lead.

Recommendation 1:

> A revised ambient air quality criterion averaged (arithmetic mean) over thirty days be set at 0.7 $\mu g/m^3$. This represents an emission limit based on Best Available Technology Economically Achievable (BATEA) for a model secondary lead smelter. Since inhalation is considered to be a minor route of exposure, a criterion of 0.7 $\mu g/m^3$ would represent an increase in total lead exposure of only 14% over a limit defined by the IOC_{pop}. The impact on soil using such a standard is estimated to be an approximate increase in lead levels of 185 ppm at the point of impingement realized over 50 years.

Recommendation 2:

> Based on the empirically derived conversion factors of 3 and 3 respectively, a half-hour point of impingement standard of 6 $\mu g/m^3$ and a 24 hour ambient air quality criterion (AAQC) of 2 $\mu g/m^3$ are recommended.

Recommendation 3:

Because of the concern associated with emissions from the lead industry, the Ministry continue air monitoring near industrial point sources of lead emissions.

Recommendation 4:

Because of the uncertainty in understanding the long-term impact on soil resulting from atmospheric deposition, the Ministry, in cooperation with the lead industry, undertake a comprehensive soil monitoring program in the vicinity of industrial point sources of lead where lead has been identified as a concern.

Recommendation 5:

The Ministry in cooperation with other regulatory agencies sponsor research into innovative means for controlling fugitive emissions from industrial sources of lead.

Recommendation 6:

The ambient air quality criterion and point of impingement standards for lead be reviewed as new information becomes available and it is deemed necessary to reassess the basis of these guidelines.

4.0 ANTICIPATED BENEFITS OF REVISED ENVIRONMENTAL STANDARDS

It has been estimated that the effects of lead exposure in children can have significant economic and non-economic costs to society. Lead exposure among children living in the United States has been estimated to impose billions of dollars annually on the U.S. economy (Levin 1986; CDC, 1991). As a result, many attempts have been made to try to understand the value of benefits of lead abatement strategies and how these values relate to cost (CDC, 1991).

In order to determine the potential benefits that revising environmental standards for lead may have in Ontario, it is necessary to examine the following relationships:

- the impact that revised environmental standards will have on blood lead levels in Ontario
- the number of children potentially affected
- the monetary value of benefits of reducing blood lead levels

While these relationships are examined in the following sections, it is acknowledged that their derivation is associated with a significant degree of uncertainty. The purpose of presenting this information is to illustrate the potential benefits of concerted programs which address all potential sources of lead exposure. This issue is discussed more fully in Sections 4.3 and 5.0.

4.1 Benefits of Reducing Blood Lead Levels

Among the benefits of preventing or reducing exposure to lead in children are the reduced or avoided adverse effects that would have resulted had exposure occurred. Table 1 (page 16) lists of some of the adverse health effects resulting from lead exposure and the associated blood lead level. The benefits for which monetized values can be provided are: the reduction in medical costs; the reduction in special education costs; and the reduction in future productivity of lead poisoned children.

These benefits are only a few of the benefits of preventing lead exposure. Many benefits cannot be quantified (e.g., avoiding the emotional cost to families of having a lead poisoned child). In addition, benefits such as preventing other health-related problems resulting from lead exposure are also not included. The reason is not because they are unimportant, particularly when summed over the population of Ontario; rather it reflects the absence of methods for estimating reliable biophysical measures of these effects.

The approach taken for this analyses was adopted from that developed by the Centers for Disease Control (CDC) for its 1991 statement on preventing lead poisoning in young children. This analyses, which is presented in detail in Appendix D examines the relationship between: blood lead levels and intelligence (measured by IQ); IQ and educational attainment; and educational attainment and lifetime productivity (measured by earning potential). The relationship between IQ and blood lead used for the analysis is a change of 0.25 IQ points for every 1 µg/dL change in blood lead. This value was selected by examining the results of six studies relating blood lead levels to IQ. This relationship assumes that there is no threshold below which blood lead levels do not affect IQ. The relationship between earning potential and IQ was determined by examining the relationships between IQ and the level of educational attainment; labour force participation; and wage rates. Using data from Ontario on historical lifetime earnings, the lifetime benefit of reducing blood lead by 1 µg/dl is estimated at $1,852 per child affected (expressed in 1993 dollars). This represents a net benefit of an approximate 0.44% increase in earning potential realized over a lifetime.

It is important to keep in mind that a similar benefits analysis can be performed for any activity which affects a child's level of educational attainment. While exposure to lead has been identified as having an indirect affect on cognitive ability, other factors such as proper nutrition, parental involvement, socio-economic status, effectiveness of a teaching system can all have a profound affect on the level of educational attainment and thus lifetime earning potential of a child. It is recognized that these factors may play an equal or even more important role than lead exposure on the level of educational attainment achieved by a child.

The CDC also evaluated the benefits of preventing blood lead levels from rising above 25 µg/dL. This analysis includes the avoided medical and special education expenses associated with classical lead poisoning. This analysis, while presented in Appendix D for reference, is not considered relevant to understanding the potential benefits of revised environmental standards because of the low incidence in Ontario of blood lead levels above 25 µg/dL resulting from exposure to traditional environmental media. The relevance of this analysis is more closely aligned with understanding the benefits of preventing cases of classical lead poisoning such as those which result from the ingestion of lead-based paint.

4.2 Relationship Between Environmental Standards and Guidelines and Blood Lead

In order to understand the potential benefits realized by revised environmental standards and guidelines, it is necessary to examine the impact that revised standards

will have on the blood lead level of children affected. Table 13 provides a comparison of blood lead levels which are predicted to result from exposure to various levels of lead in food, ambient air, soil and drinking water.

Table 13 Exposure Estimates and Predicted Blood Lead Concentrations of Various Exposure Scenarios

Exposure Scenario	Source Contribution[1] (µg/kg/day)		Daily Intake (µg/kg/day)	Predicted Blood Lead Concentration (µg/dL)
Actual - based on results from 1990 blood lead surveys	N/A		N/A	4.3[2] 3.8[3]
Predicted- based on 1985 food basket survey	Food	1.33	2.75	7.5
	Soil	1.2		
	Drinking Water	.23		
	Air	.01		
Predicted - based on projected 1993 food levels	Food	.45	1.9	5.0
	Soil	1.2		
	Drinking Water	.23		
	Air	.01		
Predicted - based on maximal exposure to current guidelines	Food	.45	4.31	11
	Soil	3.0		
	Drinking Water	.46		
	Air	.40		
Predicted - based on maximal exposure to proposed guidelines	Food	.45	2.25	5.9
	Soil	1.2		
	Drinking Water	.46		
	Air	.14		

1. Soil contribution does not include exposure via backyard vegetable consumption
2. Mean - South Riverdale Abatement Study control group (1990)
3. Mean - Ontario Blood lead survey (1990)

As discussed in Section 2.1, the predicted daily lead intake for children in Ontario is estimated to be 1.9 µg/kg/day. This estimate is based on modelling information using data on the level of lead in various media and the approximate consumption rate of each medium by children. A daily intake of 1.9 µg/kg/day roughly translates to a blood lead level of 5.0 µg/dL. This is a slight overestimate of the current situation in Ontario as survey data collected in 1990 indicates that the mean blood lead level of children between the ages of 1 and 4 years is between 3.8 and 4.3 µg/dL. A child maximally exposed to the current MOEE standards and guidelines for air, soil and drinking water would be predicted to receive a daily lead intake of 4.3 µg/kg/day. This level of intake roughly translates to a blood lead level of 11 µg/dL. Using the same approach a child maximally exposed to the revised standards and guidelines recommended in this report would receive a daily intake of 2.26 µg/day which translates to a blood lead level of 5.9 µg/dL.

This comparison can be used to illustrate that revising environmental standards for lead could potentially reduce blood lead levels in the population of concern from approximately 11 µg/dL to 6 µg/dL. Combining this information with the estimate derived above yields a potential lifetime benefit of $9,260 per child affected.

The final and perhaps most difficult step is to estimate the number of children who will potentially be affected by revised environmental standards. Recent survey data indicate that, while mean blood lead levels for children are between 3.8 and 4.3 µg/dL, 4% of children have blood lead levels in excess of 10 µg/dL. In Ontario, this represents approximately 18,000 children living in urban areas who are potentially at risk from lead poisoning (MOEE, 1993). If 18,000 is used as the number of children potentially affected by revised lead standards, the total benefit to Ontario expressed over a lifetime, would be approximately $166 million. This is considered a maximum value.

4.3 Dealing with Uncertainty

While the results presented above are illustrative of the potential benefits arising from revised environmental standards for lead, they should nevertheless be interpreted with caution. The need for caution is due to the inherent uncertainties associated with the analyses. Two significant sources of uncertainty are 1) understanding the magnitude of change in blood lead levels and hence adverse effects resulting from revised standards and 2) determining the number of children actually affected by revised standards.

Both of these areas of uncertainty derive from the fact that children are exposed to lead from many different sources. For those 18,000 children who are estimated to

have blood lead levels greater than 10 µg/dL, distinguishing between the contribution made by environmental sources (soil, drinking water and air) relative to that made by other common sources of lead such as lead-based paints, consumer products and food is essentially impossible.

The second factor which complicates issue is estimating the number of people who will actually be affected by revised standards. With the exception of a very small sub-set of the population, revised standards will have little impact on the current exposure scenario in Ontario. This is best illustrated by examining exposure to lead in soil. As discussed in Section 3.1, a revised soil clean-up guideline is not meant as a value which when exceeded triggers a clean-up. Therefore, while exposure to soil is estimated to account for 64% of lead exposure and thus represents the single biggest source of exposure, a revised clean-up guideline will not affect the tens-of-thousands of urban residences which due to historical uses of lead currently have elevated soil lead levels. For individuals living in these areas soil will continue to be a potential source of exposure.

For these reasons, exposure to lead can be expected to remain a significant public health issue for many years to come. While revised environmental standards will play their part in reducing exposure in the long term, the most effective means of addressing the health risks of lead is through concerted education programs which target areas of high risk and address all potential routes of exposure including lead-based paint and consumer products. This issue is discussed at greater length in the following section.

5.0 DEALING WITH OTHER SOURCES OF LEAD EXPOSURE

Ontario residents continue to be exposed to lead because of its persistence in the environment. For the majority of the population, exposure to lead is not a significant health concern. However, certain activities and sources of exposure can place individuals at greater risk. Because of the historical uses of lead and its persistence in the environment, the most important aspect of controlling lead exposure is parental awareness. This is especially important as children, because of natural activities such as mouthing, are at highest risk for lead exposure.

If exposure to lead is suspected, then a number of steps can be taken. Advice should be obtained from the family physician on the need for and frequency of blood lead testing. Advice should also be sought from the local Public Health Department. If lead exposure is a general concern in the community, then staff at the Public Health Department should be able to provide guidance on identifying areas of specific concern and the best ways of reducing exposure. For advice on testing soil and paint for the presence of lead, the Ministry of Environment and Energy can be contacted.

General advice which can be followed is that parents should ensure children have well balanced diets with adequate protein and foods rich in calcium (milk and milk products), iron (lean ground beef and green leafy vegetables) and zinc (green leafy vegetables). Additional information regarding general dietary recommendations can be obtained from the local public health nutritionist or dietitian. Because some early behaviours such as mouthing and eating dirt can increase exposure to lead, children should be taught the importance of personal hygiene, with emphasis on washing hands after playing outdoors and prior to eating. In addition, homes should be kept clean and free of dust.

The following sections describe situations where Ontario residents may be at higher risk of lead exposure and recommends ways of minimizing such exposure. Further details may be obtained by consulting several available references, including *The Citizen's Guide to Lead* by Barbara Wallace and Kathy Cooper for the Niagara Neighbourhood Association; the *Strategic Plan for the Elimination of Childhood Lead Poisoning* by the U.S. Department of Health and Human Services; *Case Study in Environmental Medicine: Lead Toxicity* by the Agency of Toxic Substances and Disease Registry; and *Preventing Lead Poisoning in Young Children* by the Centers for Disease Control.

5.1 Lead in the Home

5.1.1 Lead-Based House Paint

Lead and its compounds have been used extensively in both interior and exterior paints, as pigments, drying agents and rust inhibitors. Since 1975 the *Hazardous Products Act* prohibits the use of lead-based pigments in interior consumer paints and in the paint applied to children's toys and furniture. The Act further specifies that the lead content must not exceed 0.5% of the total solids content of the paint (RSC, 1986).

Lead-based paint in old or deteriorating housing is considered the biggest source of lead exposure for U.S. children. A number of cases of lead poisoning have been reported in do-it-yourself home renovators removing old lead paint. Levels of lead up to 500,000 µg/g have been reported in the dust from paint removal (Inskip and Atterbury, 1983). Exposure due to ingestion or inhalation of paint chips, dust or fumes is a particular hazard for children and pregnant women. In the United States, cases of clinical lead poisonings have been reported in children who were at home at the time of paint removal or "deleading" procedures. Recently, cases of lead poisoning in children ingesting dusts from old weathering paint or renovations have been reported in Toronto and other areas of Canada. Lead on exterior building surfaces can also weather and contribute substantially to soil levels on residential properties.

It has been estimated that as many of the 2,056,850 homes in Ontario built before 1970 may be affected by lead-based paint (MOEE, 1993). Lead-based paint was often used on window sills, door frames or trim. If interior paint is suspected of being lead-based, several strategies are recommended for dealing with the potential hazards:

- if paint is suspected of being lead-based assume that it is and take suitable precautions or have it tested

- maintain a high standard of housekeeping especially around areas which receive a great deal of wear such as window sills and near doors

- discourage children from eating paint chips

- stress the importance of good personal hygiene with particular attention being paid to the washing of hands and face prior to eating

- keep children away from areas with lead paint

- in the short-term, cover any deteriorating areas with tape or panelling

- all peeling or deteriorating areas should be repaired as soon as possible and repainted with lead-free paint

- for minor renovations, such as sanding or scraping, children be should removed from the area; the area should be carefully cleaned afterwards using wet methods; and the appropriate safety equipment should be worn

- major renovations should only be undertaken by professionals and residents should move out of the home until work is completed.

If exterior lead-based paint is found, the following are recommended:

- plant bushes close to exterior walls where lead levels are likely to be highest to make these areas inaccessible to children

- sod, cover soil with clean soil, or pave the area.

5.1.2 High Levels of Lead in Garden Soil

Elevated levels of lead in soil may be found in many older urban residential areas, particularly in areas near industrial sites. Children can be exposed to lead by playing outdoors as well as through house dust. The following strategies are recommended if elevated soil lead levels are of concern in the community:

- sod, cover the soil with clean soil, or pave the yard and children's play areas

- avoid bringing outside dirt indoors by removing outdoor shoes

- maintain a high standard of housekeeping by damp mopping with a phosphate cleanser once a week, especially on window sills and near doors; use rugs, curtains, and slipcovers that can be cleaned easily

- have forced air ducts cleaned regularly by professionals and replace furnace filters often

- keep children's toys clean and discourage mouthing activities, such as eating dirt

- have children wash hands before eating and after playing outside

- use precautions when consuming vegetables grown in lead contaminated soil. The Ministry is currently developing a revised fact sheet which will describe suitable precautions for consuming home grown vegetables.

5.1.3 High Levels of Lead in Drinking Water

The primary source of lead in drinking water is the distribution system, copper piping connected using lead solder or lead pipes. Results indicate that few areas in Ontario have recorded elevated lead levels in their drinking water (Appendix A). Areas at risk include communities where soft water or water of low pH promotes leaching of lead from the distribution system and areas where lead service lines are still in use. The following strategies are recommended if lead in drinking water is a concern in the community:

- ensure that water used for consumption is taken from cold water taps which have been flushed of standing water

- never use water directly from the hot water tap for consumptive purposes such as cooking and the preparation of baby formula

- to minimize wastage, draw drinking water from taps only after non-consumption uses such as showering and bathing have occurred. In addition, larger quantities of flushed water can be stored in the refrigerator

- be aware that some plumbing fixtures can contain lead; for example, some brass faucets may contain 3-8% lead.

5.2 Lead-containing Consumer Products

5.2.1 Lead in Food Cans

As recently as the 1980's, the largest portion of an Ontario resident's lead exposure came from food, especially canned food. In 1985, lead solder seams were used in approximately one third of the food cans manufactured in Canada. Currently, the majority of cans manufactured in North America have welded seams. However, a number of other countries have not converted their processes and as a result, many imported food tins may still be lead-soldered. Of particular concern are acid foods, such as tomatoes and fruit juices. Food should never be stored in an opened tin, as this will promote leaching of any lead present. For those canned foods which are covered under the *Food and Drug Act*, Health and Welfare Canada sets limits for lead. If in doubt, Health and Welfare Canada can be contacted for further information.

5.2.2 Lead in Housewares

A number of cases of both childhood and adult lead poisoning have occurred as a result of using lead-glazed ceramics or pewter dishes for food or beverages. Recent studies have also shown that significant quantities of lead can leach into alcoholic beverages stored in crystal decanters, crystal containing up to 30% lead oxide for increased strength and brilliance. The following precautions are recommended:

- avoid using imported or homemade ceramic dishes for serving or storing food or beverages

- avoid using pewter dishes for serving or storing food or beverages

- crystal decanters should only be used for serving, never for storage; alcoholic beverages should be stored in their original containers.

5.2.3 Lead in Hobbyist Materials

A number of arts, crafts and hobbies involve the use of lead metal, solder, paints, pigments, or ceramic glazes. These lead-rich materials are a potential source of lead poisoning for children and the following precautions are recommended:

- hobbyists should be aware of chemical content of their materials and should use appropriate gloves, goggles, respirators or other protective equipment

- work should be done in a well-ventilated area removed from the rest of the household

- store materials in a secure place out of the reach of children

- keep children away from the area where lead-containing materials are used

- keep the work area clean and clean up afterwards

- launder work clothes and cleaning materials, such as rags, separately from other household items.

5.2.4 Lead in Shot and Fishing Sinkers

It is estimated that approximately 1500 tonnes of spent lead shot enters the Canadian environment annually. The shot, which can remain suspended in soils and sediments for many years represents an acute hazard to foraging waterfowl. An estimated 1.6 - 3.8 million waterfowl die annually from acute lead poisoning. Recently, in a well publicised case in Ontario, a number of trumpeter swans in the Wye Marsh breeding colony died from ingesting lead pellets. This case was of particular significance because of the detrimental affect it had on the efforts to reintroduce breeding populations of trumpeter swans to southern Ontario.

Because of the concerns related to the death of waterfowl, many jurisdictions have banned or severely restricted the use of lead shot. In United States, the use of lead shot has been banned for most hunting activities for the past three years.

In Canada, the Canadian Wildlife Service under the authority of the *Migratory Birds Convention Act* has established a number of "non-toxic shot" zones in Canada. Hunters within these zones must use alternatives to lead shot such as steel or bismuth. Currently, there are two non-toxic shot zones in Ontario, one located on the southern shore of Lake St. Clair and second recently established at Wye Marsh. The Canadian Wildlife Service is considering the possibility of a wide-scale ban on the use of lead shot in southern Ontario by 1997. The Ministry of Environment and Energy endorses the concept of a provincial-wide ban on the use of lead shot.

For further information on the establishment of non-toxic shot zones, the Canadian Wildlife Service or the Ministry of Natural Resources can be contacted.

Lead-based fishing sinkers lost in rivers and lakes are beginning to be recognized as another source of lead poisoning for waterfowl. In the United States, approximately 2 million pounds of lead fishing sinkers are produced annually. In response to a citizens' petition seeking a requirement for warning labels on lead fishing sinkers, the United States Environmental Protection Agency is considering banning the manufacture and distribution of lead fishing sinkers in the United States. While alternatives to lead-based sinkers exist, similar actions have not been undertaken in Canada. Additional research is recommended to define the extent of the problem in Ontario.

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APPENDIX A LEAD CONCENTRATIONS FROM THE DRINKING WATER SURVEILLANCE PROGRAM

[1]Table A.1 **Lead Concentrations (μg/l) in Tap Water from the Drinking Water Surveillance Program**

PLANT	YEAR	TREATED RANGE	TREATED MEAN	TREATED N	FLUSHED RANGE	FLUSHED MEAN	FLUSHED N	OVERNIGHT RANGE	OVERNIGHT MEAN	OVERNIGHT N
AJAX	1988	0.02 - 0.48	0.18	8	0.19 - 0.19	0.19	1	1.10 - 1.10	1.10	1
	1989	0.02 - 0.22	0.06	12	0.13 - 0.63	0.32	12	0.68 - 1.60	0.96	12
	1990	0.05 - 0.13	0.06	12	0.10 - 0.65	0.24	11	0.38 - 2.20	0.88	11
	1991	0.05 - 0.32	0.10	6	0.09 - 0.34	0.21	6	0.48 - 0.92	0.73	6
	1992	0.05 - 0.08	0.06	4	0.18 - 0.45	0.28	3	0.97 - 2.70	1.72	3
ALEXANDRIA	1992	0.05 - 0.29	0.12	5	0.11 - 0.50	0.24	5	0.21 - 0.39	0.30	4
ALVINSTON	1985	3.00 - 23.00	7.67	6						
	1986	3.00 - 3.00	3.00	3						
	1987	3.00 - 3.00	3.00	1						
	1988	0.03 - 0.26	0.14	9						
	1989	ND - 0.80	0.20	12						
	1990	0.05 - 0.23	0.12	4	0.10 - 0.24	0.18	3	0.24 - 0.32	0.28	2
	1991	0.05 - 0.08	0.06	5	0.08 - 0.57	0.39	5	0.29 - 1.30	0.79	5
	1992	0.05 - 0.07	0.06	5	0.18 - 0.43	0.32	4	0.18 - 2.30	0.81	4
AMHERSTBURG	1985	3.00 - 3.00	3.00	8						
	1986	3.00 - 3.00	3.00	12						
	1987	3.00 - 3.00	3.00	2						
	1988	ND - 0.08	0.04	10						
	1989	0.03 - 0.56	0.15	12	0.13 - 0.86	0.36	11	0.24 - 2.10	1.28	11
	1990	0.05 - 0.12	0.08	6	0.07 - 0.62	0.25	10	0.08 - 1.50	0.77	10
	1991	0.05 - 1.60	0.34	6	0.07 - 1.50	0.42	7	0.96 - 7.70	4.22	7
	1992	0.05 - 0.10	0.07	6	ND - 5.40	1.37	6	0.09 - 17.00	5.15	6
ATIKOKAN	1988	0.18 - 1.70	0.70	3	0.70 - 2.30	1.55	6	5.50 - 10.00	7.23	6
	1989	0.05 - 0.67	0.33	10	0.17 - 2.30	0.98	18	ND - 9.90	4.07	18
	1990	0.05 - 0.86	0.22	12	0.51 - 2.90	1.44	20	2.20 - 75.00	16.60	20
	1991	0.05 - 0.14	0.10	6	0.41 - 9.70	1.48	11	0.71 - 14.82	4.32	11
	1992	0.07 - 0.45	0.20	6	0.51 - 0.64	0.57	5	0.45 - 9.90	5.59	5

PLANT	YEAR	TREATED RANGE	TREATED MEAN	TREATED N	FLUSHED RANGE	FLUSHED MEAN	FLUSHED N	OVERNIGHT RANGE	OVERNIGHT MEAN	OVERNIGHT N
BARRIE CENTENNIAL PARK WELL	1990			0	0.39 - 1.10	0.67	12	0.53 - 4.40	1.73	12
	1991	0.05 - 0.07	0.06	6	0.31 - 1.30	0.57	6	0.35 - 3.70	1.60	6
	1992	0.09 - 5.10	2.27	4						
BARRIE JOHNSON ST WELL	1990			0	0.41 - 0.62	0.50	8	2.40 - 18.00	5.78	8
	1991			0	0.33 - 1.70	0.69	8	0.43 - 8.70	2.66	8
	1992	0.72 - 3.00	1.46	4	0.48 - 0.48	0.48	2	1.20 - 2.30	1.75	2
BARRIE TIFFEN WELL	1990				0.17 - 2.70	0.54	12	0.28 - 2.30	0.88	12
	1991	0.06 - 0.39	0.23	4	0.20 - 0.41	0.29	6	0.22 - 3.80	1.23	6
BEARDMORE	1992	0.05 - 0.08	0.07	2	0.21 - 0.24	0.23	2	0.54 - 0.80	0.67	2
BEAVERTON	1991	0.14 - 3.80	1.52	6	1.20 - 2.10	1.69	6	3.20 - 7.40	5.66	6
	1992	0.18 - 0.80	0.41	7	0.19 - 1.90	1.09	7	2.20 - 31.00	8.61	7
BELLE RIVER	1990	0.05 - 0.09	0.06	8	0.10 - 1.00	0.45	5	0.23 - 5.90	1.70	5
	1991	0.05 - 0.14	0.06	11	0.20 - 0.57	0.37	11	0.36 - 2.40	1.18	11
	1992	0.05 - 0.16	0.07	6	0.10 - 0.42	0.24	3	0.17 - 1.40	0.64	3
BELLEVILLE	1987	3.00 - 6.00	3.56	9	3.00 - 20.00	5.32	19	3.00 - 22.00	7.95	19
	1988	0.02 - 0.08	0.05	12	ND - 3.60	0.85	24	ND - 6.10	2.95	24
	1989	0.02 - 0.96	0.21	12	0.02 - 1.30	0.33	24	0.38 - 8.80	1.91	24
	1990	0.05 - 2.50	0.48	6	0.08 - 0.28	0.17	12	0.53 - 3.40	1.38	12
	1991	0.05 - 0.19	0.12	6	0.08 - 0.40	0.17	9	0.59 - 2.00	1.37	10
	1992	0.05 - 1.50	0.43	4	0.05 - 0.19	0.15	4	0.57 - 1.50	1.14	4
BRACEBRIDGE LEADER SPRING	1991	0.07 - 0.36	0.17	8						
	1992	0.05 - 0.23	0.16	4						

		TREATED			FLUSHED			OVERNIGHT		
PLANT	YEAR	RANGE	MEAN	N	RANGE	MEAN	N	RANGE	MEAN	N
BRACEBRIDGE	1991	0.13 - 0.65	0.25	8	0.20 - 1.90	0.73	13	0.96 - 33.00	8.82	11
	1992	0.05 - 0.22	0.12	8	0.15 - 1.10	0.64	11	0.60 - 37.00	8.99	11
BRANTFORD	1987	3.00 - 3.00	3.00	1	3.00 - 10.00	4.35	20	3.00 - 81.00	11.05	20
	1988	0.09 - 0.39	0.18	12	0.26 - 6.20	1.98	24	0.65 - 57.00	18.38	24
	1989	0.13 - 0.61	0.30	12	0.25 - 9.40	3.82	23	ND - 170.00	48.46	22
	1990	0.08 - 0.21	0.14	6	0.32 - 5.70	1.92	11	0.80 - 60.00	20.60	11
	1991	0.05 - 0.40	0.16	9	0.64 - 2.90	1.61	9	1.20 - 180.00	35.03	8
	1992	0.05 - 0.32	0.12	6	1.80 - 3.80	2.49	7	7.10 - 42.00	22.87	7
BROCKVILLE	1990	0.11 - 4.00	0.63	10	0.06 - 0.58	0.24	19	0.33 - 2.60	0.93	19
	1991	0.05 - 0.22	0.13	11	0.07 - 1.80	0.44	18	0.08 - 2.00	0.81	18
	1992	0.11 - 0.27	0.20	4	0.22 - 1.50	0.57	4	0.30 - 1.10	0.57	4
BURLINGTON	1987	3.00 - 7.00	3.33	12	ND - 5.00	3.15	20	3.00 - 54.00	7.75	20
	1988	0.02 - 1.10	0.15	12	0.02 - 0.88	0.28	12	ND - 7.60	2.05	12
	1989	0.02 - 0.30	0.09	12	0.40 - 6.70	1.32	12	ND - 10.00	5.30	12
	1990	0.05 - 0.20	0.08	6	0.13 - 2.10	0.56	6	0.89 - 3.90	1.73	6
	1991	0.05 - 0.81	0.23	6	0.55 - 4.50	1.83	6	1.40 - 71.00	18.90	6
	1992	0.05 - 0.12	0.08	4	0.31 - 1.00	0.55	4	0.39 - 7.50	2.62	4
CAMBRIDGE WELL (P11)	1991	0.05 - 0.23	0.09	11						
	1992	0.05 - 0.35	0.16	3						
CAMBRIDGE WELL (G3)	1991	0.24 - 0.59	0.36	11						
	1992	0.13 - 0.38	0.25	4						
CASSELMAN	1989	0.18 - 0.88	0.67	9	0.30 - 2.60	0.89	18	0.60 - 71.00	7.27	18
	1990	0.06 - 0.91	0.38	12	0.27 - 1.10	0.65	24	0.41 - 24.00	5.01	24
	1991	0.06 - 2.60	0.46	10	0.13 - 2.20	0.67	18	1.10 - 100.00	8.91	18
	1992	0.20 - 0.52	0.33	6	0.43 - 1.40	0.77	6	0.72 - 13.00	3.34	6

PLANT	YEAR	TREATED RANGE			TREATED MEAN	TREATED N	FLUSHED RANGE			FLUSHED MEAN	FLUSHED N	OVERNIGHT RANGE			OVERNIGHT MEAN	OVERNIGHT N
CAYUGA	1987	3.00	-	3.00	3.00	1										
	1988	0.12	-	0.61	0.29	10	0.24	-	0.93	0.52	9	2.20	-	4.10	3.04	7
	1989	0.20	-	3.10	0.63	12	0.35	-	0.35	0.35	1	5.30	-	5.30	5.30	1
	1990	0.12	-	0.78	0.28	13										
	1991	0.07	-	0.43	0.18	6										
	1992	0.10	-	0.33	0.17	6										
CHAPLEAU	1991	0.05	-	0.08	0.06	8	0.18	-	0.74	0.43	6	1.60	-	5.30	2.90	6
	1992	0.05	-	0.24	0.08	8	0.26	-	2.20	0.75	7	2.20	-	10.00	4.24	7
CHARLOTTENBURG	1991	0.05	-	0.44	0.13	10	0.16	-	0.25	0.21	2	1.70	-	1.70	1.70	2
	1992	0.05	-	0.93	0.19	8	0.22	-	1.10	0.43	8	0.52	-	5.50	2.34	8
CHATHAM	1988	0.12	-	0.12	0.12	1	0.28	-	0.58	0.43	2	0.77	-	9.40	5.09	2
	1989	0.09	-	1.30	0.42	12	0.24	-	8.70	1.01	21	0.48	-	13.00	5.97	18
	1990	0.08	-	2.80	0.67	12	0.11	-	6.70	0.78	20	0.84	-	9.00	4.40	12
	1991	0.47	-	2.70	1.54	6	0.06	-	1.60	0.51	10	2.60	-	15.00	8.27	3
	1992	1.80	-	8.00	4.05	4	0.34	-	2.30	1.11	4	9.30	-	26.00	18.33	4
COBOURG	1991	0.05	-	0.25	0.11	6	0.31	-	0.56	0.42	6	1.31	-	5.30	3.90	4
	1992	0.05	-	0.99	0.21	8	0.20	-	0.80	0.46	6	0.42	-	27.00	7.32	6
CORNWALL	1987	3.00	-	3.00	3.00	4	3.00	-	8.00	3.50	18	3.00	-	10.00	4.78	18
	1988	0.02	-	0.36	0.12	12	0.19	-	2.40	0.61	23	0.95	-	34.00	5.29	23
	1989	0.06	-	0.34	0.20	11	0.14	-	4.10	0.77	23	1.10	-	9.21	4.38	22
	1990	0.06	-	0.32	0.11	6	0.10	-	0.77	0.39	12	0.94	-	6.20	3.39	11
	1991	0.05	-	0.24	0.09	6	0.15	-	0.56	0.31	11	1.30	-	6.10	3.56	10
	1992	0.08	-	0.12	0.11	4	0.16	-	0.58	0.31	4	0.50	-	4.70	2.70	4
DELHI	1990	0.05	-	2.50	0.66	10	0.13	-	0.59	0.29	9	0.09	-	2.40	0.84	8
	1991	0.07	-	4.10	1.35	11	0.05	-	0.32	0.19	10	0.32	-	1.50	0.77	10
	1992	0.09	-	1.50	0.68	6	0.12	-	0.20	0.17	4	0.27	-	0.51	0.34	4

		TREATED			FLUSHED			OVERNIGHT		
PLANT	YEAR	RANGE	MEAN	N	RANGE	MEAN	N	RANGE	MEAN	N
DELHI SPRING SUPPLY	1990	0.05 - 0.32	0.12	10	0.34 - 0.74	0.48	10	2.30 - 4.90	3.58	9
	1991	0.05 - 0.08	0.06	11	0.20 - 0.55	0.38	11	1.50 - 3.60	2.42	11
	1992	0.05 - 0.10	0.08	4	0.24 - 0.46	0.34	4	1.80 - 3.30	2.58	4
DESERONTO	1987	3.00 - 5.00	3.33	6	3.00 - 8.00	3.83	6	3.00 - 6.00	3.67	6
	1988	0.02 - 0.47	0.29	13	0.05 - 0.66	0.36	12	1.80 - 3.40	2.60	12
	1989	ND - 1.40	0.57	12	0.07 - 1.30	0.67	12	2.10 - 8.30	3.74	12
	1990	0.06 - 0.59	0.29	7	0.19 - 0.67	0.34	7	1.90 - 3.30	2.72	6
	1991	0.19 - 0.66	0.35	6	0.19 - 0.57	0.34	6	1.70 - 2.80	2.22	6
	1992	0.32 - 0.81	0.58	4	0.37 - 0.91	0.60	4	1.90 - 3.70	2.63	4
DRESDEN	1985	3.00 - 9.00	3.86	7						
	1986	3.00 - 3.00	3.00	6						
	1987	3.00 - 11.00	7.00	2						
	1988	0.02 - 0.33	0.12	15	ND - 1.30	0.34	22	1.20 - 25.00	5.16	22
	1989	0.02 - 2.10	0.41	13	0.10 - 3.60	0.72	21	1.50 - 17.00	5.02	20
	1990	0.09 - 0.70	0.22	7	0.22 - 0.75	0.43	11	1.80 - 16.00	4.72	11
	1991	0.05 - 0.19	0.11	6	0.12 - 0.43	0.29	10	0.95 - 12.00	3.66	10
	1992	0.06 - 1.10	0.42	6	0.23 - 2.00	0.72	6	4.30 - 31.00	11.05	6
DRYDEN	1988	0.07 - 0.22	0.14	3	0.11 - 0.15	0.13	3	0.60 - 0.91	0.79	3
	1989	0.02 - 0.70	0.19	12	0.02 - 0.46	0.15	10	0.52 - 6.40	1.44	10
	1990	0.05 - 0.46	0.12	12	0.05 - 0.47	0.19	9	0.19 - 77.00	10.60	9
	1991	0.05 - 0.09	0.06	6	0.18 - 0.79	0.35	5	1.00 - 5.60	3.80	3
	1992	0.05 - 0.14	0.08	4	0.08 - 0.50	0.23	4	0.96 - 11.00	5.98	2
DUNNVILLE	1990	0.05 - 0.07	0.06	4	0.09 - 0.28	0.19	2	0.22 - 0.22	0.22	1
	1991	0.05 - 0.21	0.10	12						
	1992	0.05 - 0.15	0.08	4						

		TREATED			FLUSHED			OVERNIGHT		
PLANT	YEAR	RANGE	MEAN	N	RANGE	MEAN	N	RANGE	MEAN	N
ELMIRA WELL (E5A)	1988	0.02 - 0.12	0.09	8						
	1989	0.04 - 0.31	0.17	11						
	1990			0	0.27 - 0.77	0.39	11	2.70 - 15.00	8.37	11
	1991			0	0.30 - 3.40	0.93	6	5.80 - 7.60	6.95	6
	1992	0.05 - 0.11	0.08	3	0.20 - 0.42	0.29	4	0.05 - 6.80	4.34	4
ELMIRA WELL (E9)	1988	0.12 - 0.41	0.25	8	0.22 - 2.80	0.72	6	1.50 - 23.00	6.93	6
	1989	0.13 - 1.30	0.48	10	0.32 - 2.40	0.95	11	2.10 - 33.00	11.10	11
EMO	1991	0.05 - 1.30	0.29	11	0.19 - 0.67	0.38	11	0.70 - 5.70	2.08	10
	1992	0.05 - 0.07	0.05	7	0.17 - 5.60	1.12	7	0.15 - 1.80	1.22	7
FORT ERIE	1987	ND - 8.00	3.33	6	ND - 9.00	3.71	14	ND - 11.00	4.31	13
	1988	0.02 - 0.25	0.07	12	0.12 - 0.92	0.36	19	0.11 - 3.10	1.82	19
	1989	0.02 - 1.10	0.21	12	0.25 - 1.80	0.68	17	0.25 - 4.80	2.07	17
	1990	0.05 - 0.09	0.07	6	0.19 - 0.80	0.45	11	0.79 - 11.00	2.66	11
	1991	0.05 - 0.25	0.09	6	0.18 - 0.61	0.38	10	0.71 - 2.70	1.31	10
	1992	0.05 - 0.06	0.05	4	0.27 - 0.86	0.51	3	1.60 - 2.50	1.97	3
FORT FRANCES	1988	0.11 - 0.11	0.11	1	37.00 - 37.00	37.00	1	57.00 - 57.00	57.00	1
	1989	0.06 - 1.50	0.31	12	0.22 - 8.90	3.15	21	0.38 - 66.00	8.31	22
	1990	0.05 - 0.58	0.18	12	0.05 - 51.00	5.82	23	0.42 - 59.00	10.51	24
	1991	0.07 - 0.30	0.19	2	0.11 - 3.40	1.13	4	1.70 - 9.30	4.38	4
	1992	0.05 - 0.16	0.09	5	0.09 - 1.60	0.68	6	1.10 - 30.57	14.65	6
GODERICH	1992	0.05 - 0.54	0.11	9	0.37 - 1.10	0.77	9	0.93 - 3.80	2.44	8
GRAVENHURST	1990	0.11 - 57.00	5.65	11	0.47 - 2.90	0.97	11	0.93 - 40.00	7.88	11
	1991	0.19 - 5.90	1.03	11	0.21 - 1.30	0.63	11	0.84 - 58.00	13.45	11
	1992	0.05 - 1.90	0.91	6	0.24 - 1.20	0.65	6	1.10 - 44.00	10.73	6

		TREATED			FLUSHED			OVERNIGHT		
PLANT	YEAR	RANGE	MEAN	N	RANGE	MEAN	N	RANGE	MEAN	N
GRIMSBY	1987	ND - 7.00	2.78	9	3.00 - 8.00	3.82	11	ND - 11.00	4.09	11
	1988	0.02 - 0.42	0.10	12	0.18 - 0.29	0.23	12	0.62 - 25.00	4.25	12
	1989	0.02 - 0.38	0.11	12	0.34 - 1.20	0.74	12	1.80 - 74.00	20.48	12
	1990	0.05 - 0.80	0.25	6	0.37 - 1.30	0.58	6	0.61 - 44.00	20.60	6
	1991	0.09 - 0.35	0.23	6	0.34 - 7.80	1.74	6	2.10 - 38.00	14.77	6
	1992	0.07 - 0.50	0.25	4	0.32 - 0.48	0.41	4	1.30 - 6.80	3.40	4
GUELPH PAISLEY ROAD WELL	1990	0.20 - 0.34	0.28	5	0.73 - 1.30	0.96	5	2.00 - 25.00	8.50	5
	1991	0.17 - 0.27	0.22	7	0.73 - 1.60	1.05	9	3.30 - 13.00	6.89	8
	1992	0.16 - 3.00	1.58	2	0.80 - 4.30	2.55	2	0.79 - 2.80	1.80	2
U OF GUELPH PUMPING STATION	1990	2.10 - 4.80	3.48	5						
	1991	2.00 - 2.60	2.34	7						
	1992	2.70 - 2.70	2.70	1						
GUELPH WELL SUPPLY	1990	0.26 - 0.36	0.31	5	0.39 - 0.66	0.52	5	0.38 - 2.40	1.50	4
	1991	0.19 - 0.26	0.23	7	0.30 - 0.61	0.46	8	0.61 - 1.80	1.19	8
	1992			0						
HALDIMAND/NORFOLK	1989	0.02 - 0.64	0.19	9	0.29 - 2.00	0.79	12	0.70 - 16.00	4.93	12
	1990	0.05 - 0.16	0.07	13	0.09 - 1.10	0.47	12	0.44 - 8.30	2.93	11
	1991	0.05 - 0.09	0.06	7	0.17 - 0.38	0.28	7	0.42 - 26.00	5.15	7
	1992	0.05 - 0.06	0.05	4	0.77 - 2.80	1.69	4	3.20 - 7.30	4.40	4
HAMILTON	1986	3.00 - 4.00	3.20	5	3.00 - 6.00	4.17	6	3.00 - 10.00	5.50	6
	1987	ND - 10.00	3.33	12	3.00 - 14.00	3.61	23	3.00 - 28.00	6.00	23
	1988	0.09 - 0.56	0.24	12	0.33 - 2.40	0.77	24	0.73 - 7.00	2.93	24
	1989	0.02 - 0.37	0.16	11	0.36 - 5.00	1.56	23	0.72 - 11.00	3.45	23
	1990	0.05 - 0.09	0.06	6	0.41 - 4.70	1.64	12	1.20 - 3.70	2.15	12
	1991	0.05 - 0.09	0.06	6	0.31 - 8.90	2.05	12	0.56 - 17.00	4.08	12
	1992	0.05 - 0.20	0.13	4	0.21 - 6.70	2.76	4	0.77 - 15.00	6.49	4

PLANT	YEAR	TREATED RANGE		MEAN	N	FLUSHED RANGE		MEAN	N	OVERNIGHT RANGE		MEAN	N
HARROW-COLCHESTER	1985	3.00 -	4.00	3.13	8								
	1986	3.00 -	3.00	3.00	5								
	1987	3.00 -	3.00	3.00	2								
	1988	0.08 -	0.16	0.12	2								
	1989	0.04 -	0.19	0.12	2								
	1990	0.05 -	0.15	0.09	7	0.05 -	0.38	0.18	14	0.20 -	1.30	0.74	12
	1991	0.05 -	0.09	0.07	6	0.11 -	0.86	0.32	11	0.06 -	3.30	0.95	11
	1992	0.05 -	0.14	0.08	4	0.08 -	0.12	0.09	3	0.83 -	1.30	1.01	3
HAWKESBURY	1989	0.02 -	0.39	0.16	9	0.22 -	3.50	0.69	18	0.18 -	6.00	2.51	18
	1990	0.05 -	1.20	0.18	12	ND -	0.70	0.29	24	0.45 -	6.20	2.05	24
	1991	0.07 -	0.70	0.21	10	0.12 -	0.64	0.31	18	0.38 -	3.10	1.22	18
	1992	0.05 -	0.26	0.10	4	0.15 -	0.42	0.29	4	0.78 -	3.22	1.70	4
HUNTSVILLE	1992	0.05 -	0.08	0.07	2	3.40 -	13.00	8.20	2				
KENORA	1988	0.10 -	0.10	0.10	1	0.50 -	1.40	0.95	2	4.30 -	7.50	5.90	2
	1989	ND -	37.00	5.30	12	0.47 -	3.50	1.07	13	ND -	31.00	8.18	14
	1990	0.12 -	2.30	0.75	12	1.10 -	19.00	3.67	10	2.10 -	78.00	26.82	10
	1991	0.42 -	2.30	1.21	6	0.57 -	1.50	1.06	7	1.70 -	48.00	13.30	6
	1992	1.50 -	3.90	2.73	4	0.41 -	2.00	0.96	5	3.90 -	10.00	6.33	4
KINGSTON	1985	2.00 -	3.00	2.86	7								
	1986	3.00 -	5.00	3.23	13	ND -	3.00	2.77	13	3.00 -	22.00	5.15	13
	1987	3.00 -	3.00	3.00	12	ND -	5.00	3.08	24	3.00 -	17.00	5.42	24
	1988	ND -	0.65	0.14	12	0.11 -	0.63	0.28	23	0.34 -	14.00	4.79	23
	1989	0.02 -	0.30	0.11	12	0.08 -	1.30	0.38	20	0.38 -	16.00	5.07	20
	1990	0.05 -	0.09	0.06	6	0.08 -	0.25	0.15	6	0.33 -	0.60	0.47	6
	1991	0.05 -	0.22	0.09	6	0.09 -	0.21	0.16	6	0.37 -	0.57	0.48	6
	1992	0.05 -	0.10	0.08	4	0.08 -	0.17	0.14	4	0.49 -	1.40	0.76	4
KITCHENER (RECHARGE WELL)	1987	3.00 -	3.00	3.00	10								
	1988	0.46 -	1.30	0.84	12								
	1989	0.58 -	1.60	1.03	12								
	1992	0.10 -	0.34	0.22	2								

PLANT	YEAR	TREATED RANGE	MEAN	N	FLUSHED RANGE	MEAN	N	OVERNIGHT RANGE	MEAN	N
KITCHENER (RESERVOIR)	1987	3.00 - 3.00	3.00	8						
	1988	0.11 - 0.48	0.22	12						
	1989	0.04 - 1.30	0.30	12						
	1990	0.06 - 0.29	0.11	6						
	1991	0.07 - 0.15	0.10	6						
	1992	0.05 - 0.09	0.07	4						
KITCHENER MANNHEIM	1992	0.05 - 0.41	0.18	8						
KITCHENER WELL SUPPLY	1987	3.00 - 6.00	3.27	11						
	1988	0.23 - 68.00	5.93	12	0.03 - 1.20	0.25	12	0.02 - 38.00	5.81	12
	1989	0.03 - 0.73	0.18	12	0.16 - 0.94	0.55	12	1.80 - 20.00	8.48	12
	1990	0.05 - 0.35	0.16	6	0.15 - 0.27	0.20	6	0.84 - 3.70	2.04	6
	1991	0.13 - 0.86	0.39	6	0.14 - 0.23	0.18	5	0.53 - 2.20	1.29	5
	1992	0.05 - 0.23	0.12	3	0.63 - 0.89	0.72	3	7.50 - 15.00	10.50	3
LINDSAY	1989	0.02 - 0.91	0.46	9	0.32 - 2.40	0.85	19	2.00 - 10.00	5.30	17
	1990	0.10 - 0.45	0.23	11	0.20 - 1.80	0.71	19	0.49 - 7.20	3.06	19
	1991	0.14 - 2.30	0.58	9	0.17 - 2.50	0.78	16	1.10 - 25.00	4.59	17
	1992	0.12 - 0.36	0.26	5	0.39 - 0.66	0.55	5	1.40 - 11.00	4.58	5
LONDON (LAKE HURON)	1986	3.00 - 3.00	3.00	7	3.00 - 3.00	3.00	11	3.00 - 400.00	52.18	11
	1987	ND - 4.00	2.83	12	ND - 9.00	3.76	17	ND - 63.00	21.67	12
	1988	0.03 - 4.80	0.52	12	0.23 - 1.80	0.66	9	16.00 - 32.00	24.00	2
	1989	ND - 0.83	0.12	24	ND - 2.00	0.58	13	22.00 - 22.00	22.00	1
	1990	0.05 - 0.74	0.21	12	0.06 - 0.63	0.31	5			
	1991	0.05 - 0.85	0.23	12	0.20 - 0.40	0.29	6	1.60 - 2.20	1.90	2
	1992	ND - 0.41	0.17	7						
MANITOUWADGE WELL (1,3,RES)	1991	0.05 - 2.00	0.24	11	0.25 - 0.61	0.40	11	0.13 - 3.30	1.71	10
	1992	0.05 - 0.16	0.09	3	0.19 - 0.37	0.31	3	1.40 - 4.50	3.13	3
MARATHON WELL SUPPLY	1991	ND - 0.19	0.10	7	0.38 - 7.90	1.58	7	0.59 - 11.00	5.02	4
	1992	0.05 - 0.12	0.09	5	0.47 - 2.10	0.88	5			

PLANT	YEAR	TREATED RANGE	TREATED MEAN	TREATED N	FLUSHED RANGE	FLUSHED MEAN	FLUSHED N	OVERNIGHT RANGE	OVERNIGHT MEAN	OVERNIGHT N
METRO TORONTO (EASTERLY)	1986	3.00 - 3.00	3.00	8						
	1987	ND - 4.00	2.83	12	3.00 - 5.00	3.25	12	3.00 - 6.00	3.55	11
	1988	0.17 - 0.56	0.36	12	0.10 - 0.88	0.29	19	0.17 - 9.40	1.84	17
	1989	0.35 - 2.80	0.98	12	0.12 - 9.50	1.05	21	0.60 - 8.30	3.56	21
	1990	0.23 - 0.49	0.37	6	0.06 - 0.76	0.36	11	0.73 - 6.80	3.75	10
	1991	0.05 - 0.42	0.17	6	0.13 - 0.42	0.29	9	0.37 - 4.20	2.45	9
	1992	0.06 - 0.09	0.07	4	0.19 - 0.57	0.35	4	0.98 - 4.20	2.35	4
METRO TORONTO (R.C. HARRIS)	1986	3.00 - 3.00	3.00	8						
	1987	3.00 - 6.00	3.40	10	3.00 - 6.00	3.67	9	3.00 - 42.00	17.75	8
	1988	0.04 - 0.62	0.27	12	0.47 - 1.70	0.82	9	4.00 - 24.00	15.53	8
	1989	0.12 - 0.69	0.32	12	0.63 - 0.63	0.63	1	18.00 - 18.00	18.00	1
	1990	0.07 - 0.41	0.20	6						
	1991	0.16 - 0.63	0.28	6						
	1992	0.11 - 0.22	0.17	4						
METRO TORONTO (R.L. CLARK)	1986	3.00 - 5.00	3.25	8						
	1987	3.00 - 4.00	3.08	12	ND - 4.00	2.82	11	3.00 - 5.00	3.36	11
	1988	0.03 - 0.34	0.10	12	0.16 - 0.23	0.19	10	0.56 - 2.00	1.03	10
	1989	0.02 - 0.60	0.18	12	0.15 - 1.10	0.44	11	0.79 - 5.20	1.95	11
	1990	0.05 - 0.14	0.08	6	0.68 - 7.70	4.19	2	11.00 - 11.00	11.00	2
	1991	ND - 0.09	0.06	6	0.21 - 14.00	4.59	10	0.97 - 77.00	19.33	10
	1992	0.10 - 0.14	0.13	4	0.11 - 8.70	3.89	4	0.42 - 12.00	6.22	4
METRO TORONTO ISLAND	1990	0.20 - 0.46	0.31	5	0.05 - 0.05	0.05	1	0.05 - 0.05	0.05	1
	1991	0.09 - 0.25	0.17	5						
	1992	0.05 - 0.17	0.10	5						
MILTON WELL SUPPLY	1990			0	0.17 - 4.00	1.29	7	0.23 - 6.50	2.86	7
	1991			0	0.47 - 3.50	1.31	9	1.10 - 3.60	1.99	9
	1992			0	1.30 - 1.50	1.40	2	1.40 - 3.50	2.45	2
MILTON WALKERS LINE	1990				0.39 - 5.20	1.23	7	0.49 - 4.90	1.57	7
	1991				0.26 - 1.10	0.55	9	0.16 - 1.40	0.91	9
	1992				0.19 - 0.57	0.38	2	0.26 - 0.54	0.40	2

		TREATED			FLUSHED			OVERNIGHT		
PLANT	YEAR	RANGE	MEAN	N	RANGE	MEAN	N	RANGE	MEAN	N
MITCHELLS BAY	1985	3.00 - 3.00	3.00	8						
	1986	3.00 - 5.00	3.20	10						
	1987	3.00 - 3.00	3.00	2						
	1988	0.30 - 1.60	0.72	9						
	1989	0.44 - 9.90	2.05	12						
	1990	0.45 - 0.73	0.64	6						
	1991	0.33 - 21.00	4.06	6						
	1992	0.22 - 0.70	0.42	6						
NAPANEE	1991	0.07 - 0.52	0.15	9	0.15 - 0.42	0.28	9	0.30 - 4.10	1.59	8
	1992	0.05 - 0.17	0.08	8	0.08 - 0.31	0.15	8	0.12 - 3.60	.0.93	8
NIAGARA FALLS	1985	3.00 - 3.00	3.00	1	3.00 - 3.00	3.00	3	3.00 - 3.00	3.00	3
	1986	3.00 - 5.00	3.13	15	3.00 - 5.00	3.09	32	3.00 - 7.00	3.29	31
	1987	3.00 - 4.00	3.17	12	3.00 - 11.00	3.48	31	3.00 - 8.00	3.93	29
	1988	0.02 - 0.19	0.06	12	0.05 - 0.28	0.16	30	0.34 - 7.90	2.16	30
	1989	0.02 - 0.27	0.09	12	0.02 - 1.10	0.39	29	0.33 - 44.00	7.03	29
	1990	0.05 - 0.07	0.06	6	0.05 - 0.63	0.27	15	0.28 - 25.00	5.84	15
	1991	0.05 - 0.15	0.07	6	0.05 - 0.45	0.16	15	0.23 - 26.00	4.75	14
	1992	0.05 - 0.09	0.06	4	0.07 - 0.22	0.16	4	0.15 - 2.10	0.78	4
NIPIGON	1991	0.05 - 0.19	0.10	11	0.05 - 0.39	0.24	11	0.94 - 2.70	1.73	10
	1992	0.05 - 0.14	0.09	8	0.20 - 4.60	0.87	8	0.72 - 4.30	1.90	.8
NORTH BAY	1987			0	ND - 15.00	3.78	18	3.00 - 460.00	40.72	18
	1988			0	0.55 - 30.00	3.60	22	1.60 - 220.00	25.25	22
	1989	0.02 - 0.35	0.21	5	0.75 - 7.10	2.88	21	1.40 - 91.00	27.39	21
	1990	0.09 - 0.39	0.17	12	0.16 - 4.70	1.92	20	4.90 - 68.00	23.07	20
	1991	0.05 - 0.29	0.14	6	ND - 3.50	1.36	11	0.54 - 460.00	55.52	11
	1992	0.06 - 0.56	0.33	4	0.53 - 3.40	1.71	4	1.40 - 52.00	15.13	4

		TREATED			FLUSHED			OVERNIGHT		
PLANT	YEAR	RANGE	MEAN	N	RANGE	MEAN	N	RANGE	MEAN	N
OAKVILLE	1990	0.05 - 0.34	0.19	6	0.08 - 0.23	0.15	6	0.76 - 21.00	4.74	6
	1991	0.05 - 0.20	0.12	11	0.06 - 0.29	0.13	11	0.86 - 11.00	3.60	11
	1992	0.05 - 0.08	0.07	4	0.05 - 0.12	0.10	4	0.85 - 1.50	1.19	4
ODESSA	1988	0.06 - 0.35	0.18	12	0.43 - 4.50	1.74	10	3.20 - 24.00	8.88	9
	1989	0.08 - 0.36	0.23	12	0.19 - 2.40	1.35	12	2.60 - 9.30	5.10	12
	1990	0.05 - 0.18	0.11	10	0.52 - 2.70	1.00	9	1.30 - 3.70	2.52	9
	1991	0.08 - 0.29	0.16	6	0.29 - 0.58	0.43	5	0.45 - 1.30	0.80	5
	1992	0.10 - 0.23	0.18	4	0.59 - 0.92	0.81	4	0.47 - 7.30	3.54	4
OHSWEKEN	1992	0.24 - 0.67	0.47	8						
ORANGEVILLE WELL SUPPLY	1992	0.10 - 0.54	0.31	5	0.28 - 1.20	0.56	5	0.59 - 2.20	1.37	4
OSHAWA	1987	3.00 - 3.00	3.00	8	3.00 - 12.00	3.70	20	3.00 - 7.00	4.25	20
	1988	0.02 - 0.21	0.10	12	0.19 - 0.52	0.32	20	1.70 - 4.60	2.68	20
	1989	0.03 - 0.35	0.12	12	0.18 - 3.80	0.75	22	ND - 20.00	3.44	22
	1990	0.05 - 0.15	0.09	6	0.17 - 0.70	0.32	12	1.60 - 3.60	2.31	12
	1991	0.05 - 0.19	0.08	6	0.08 - 0.63	0.31	11	1.30 - 4.90	2.66	11
	1992	0.05 - 0.10	0.07	4	0.18 - 0.31	0.23	4	1.20 - 3.50	2.25	4
OTTAWA (BRITANNIA)	1986	3.00 - 4.00	3.25	4	3.00 - 4.00	3.25	8	3.00 - 6.00	4.00	8
	1987	3.00 - 8.00	3.42	12	3.00 - 4.00	3.08	24	ND - 21.00	6.54	24
	1988	0.02 - 0.19	0.08	12	0.06 - 2.10	0.71	24	0.76 - 41.00	15.67	24
	1989	0.02 - 0.47	0.15	12	0.09 - 1.20	0.66	21	0.96 - 37.00	9.53	22
	1990	0.05 - 0.08	0.06	6	0.15 - 4.60	0.75	11	0.64 - 7.80	4.63	10
	1991	ND - 0.10	0.06	9	ND - 0.81	0.37	14	ND - 13.00	4.22	13
	1992	0.05 - 0.14	0.09	4	0.32 - 0.78	0.55	2	2.20 - 6.70	4.13	3

PLANT	YEAR	TREATED RANGE	TREATED MEAN	TREATED N	FLUSHED RANGE	FLUSHED MEAN	FLUSHED N	OVERNIGHT RANGE	OVERNIGHT MEAN	OVERNIGHT N
OTTAWA (LEMIEUX ISLAND)	1986	3.00 - 4.00	3.25	4	3.00 - 4.00	3.25	8	3.00 - 25.00	10.13	8
	1987	3.00 - 5.00	3.17	12	3.00 - 22.00	5.46	24	3.00 - 220.00	17.83	24
	1988	0.02 - 0.40	0.14	12	0.09 - 4.60	1.33	23	0.23 - 27.00	7.23	23
	1989	0.02 - 0.72	0.24	12	0.13 - 4.50	1.52	23	0.37 - 20.00	6.41	23
	1990	0.05 - 0.05	0.05	6	0.11 - 2.10	0.86	11	1.50 - 18.00	5.70	11
	1991	0.05 - 0.57	0.17	6	0.20 - 2.40	0.96	11	1.90 - 11.00	5.18	11
	1992	0.08 - 0.18	0.12	4	0.26 - 2.70	1.41	4	4.70 - 11.00	7.25	4
OWEN SOUND	1990	0.14 - 0.49	0.25	10	0.33 - 0.62	0.45	10	0.62 - 5.10	2.74	10
	1991	0.05 - 0.45	0.17	11	0.21 - 0.73	0.40	11	0.51 - 4.00	1.79	10
	1992	0.06 - 0.21	0.13	4	0.23 - 0.67	0.51	3	0.61 - 9.50	6.10	3
OWEN SOUND SPRING SUPPLY	1990			0	0.33 - 0.81	0.57	10	0.34 - 0.84	0.64	8
	1991			0	0.34 - 1.00	0.67	8	0.37 - 0.96	0.61	8
	1992			0	0.46 - 0.73	0.57	3	0.66 - 1.50	1.01	3
PEMBROKE	1992	0.05 - 1.20	0.20	11	0.20 - 1.20	0.56	11	1.40 - 14.00	5.19	10
PERTH	1992	0.05 - 0.30	0.11	9	0.13 - 0.34	0.25	9	0.63 - 9.50	2.63	8
PETERBOROUGH	1987	3.00 - 3.00	3.00	8	ND - 4.00	2.96	24	3.00 - 20.00	7.38	24
	1988	0.02 - 0.26	0.09	12	0.59 - 1.50	1.03	21	5.10 - 15.00	8.02	21
	1989	0.02 - 0.35	0.13	12	0.61 - 2.30	1.25	23	5.30 - 25.00	9.33	23
	1990	0.05 - 0.14	0.08	6	0.08 - 7.10	1.41	11	0.76 - 14.00	6.29	11
	1991	0.05 - 0.36	0.10	6	0.44 - 2.30	1.13	11	3.50 - 15.00	6.61	11
	1992	0.05 - 1.20	0.26	6	0.33 - 1.20	0.54	6	1.30 - 5.40	3.53	6
PICTON	1991	0.22 - 0.58	0.40	4	0.14 - 1.00	0.37	8	0.58 - 1.50	1.06	7
	1992	0.14 - 0.32	0.24	10	ND - 0.50	0.28	18	0.81 - 3.70	2.03	18
PLANTAGENET	1990	0.05 - 0.23	0.10	5	0.14 - 0.55	0.29	5	0.61 - 1.10	0.88	5
	1991	0.05 - 0.15	0.08	11	0.08 - 0.44	0.20	10	0.12 - 2.00	0.93	10
	1992	0.05 - 0.11	0.06	6	0.18 - 0.85	0.37	6	0.62 - 3.10	1.80	6

PLANT	YEAR	TREATED RANGE	TREATED MEAN	TREATED N	FLUSHED RANGE	FLUSHED MEAN	FLUSHED N	OVERNIGHT RANGE	OVERNIGHT MEAN	OVERNIGHT N
PORT COLBORNE	1990	0.11 - 0.33	0.19	9	0.30 - 0.75	0.53	9	1.50 - 3.40	2.19	8
	1991	0.05 - 0.67	0.15	11	0.12 - 0.34	0.26	10	0.77 - 2.60	1.91	10
	1992	0.05 - 0.15	0.09	4	0.14 - 0.30	0.24	4	0.65 - 2.00	1.26	4
PORT DOVER	1987	3.00 - 14.00	4.10	10	ND - 8.00	3.06	18	ND - 29.00	7.67	18
	1988	0.02 - 0.30	0.08	12	0.08 - 9.00	0.83	22	0.95 - 22.00	7.90	21
	1989	0.02 - 0.29	0.09	12	0.11 - 1.30	0.42	10	ND - 2.10	1.39	10
	1990	0.05 - 0.17	0.09	6	0.15 - 0.27	0.20	5	0.87 - 3.00	1.95	5
	1991	0.05 - 0.25	0.09	6						
	1992	0.05 - 0.12	0.07	4						
PORT DOVER SPRING SUPPLY	1987	3.00 - 3.00	3.00	8						
	1988	0.08 - 0.26	0.16	9						
	1989	0.05 - 0.46	0.25	9						
	1990	0.05 - 0.21	0.13	6						
	1991	0.05 - 0.27	0.14	6						
	1992	0.21 - 0.22	0.22	2						
PORT ELGIN	1992	0.05 - 0.07	0.05	9	0.15 - 1.40	0.85	9	1.30 - 37.00	11.02	8
PORT HOPE	1991	0.05 - 1.80	0.29	10	0.06 - 1.50	0.61	20	0.26 - 63.00	9.11	19
	1992	0.05 - 0.44	0.17	8	0.14 - 0.61	0.38	13	0.67 - 220.00	24.46	12
PORT ROWAN	1992	0.07 - 0.09	0.08	2	0.15 - 0.17	0.16	2	0.83 - 0.83	0.83	1
PORT STANLEY	1985	3.00 - 3.00	3.00	6						
	1986	3.00 - 3.00	3.00	6						
	1987	3.00 - 4.00	3.50	2						
	1988	0.18 - 0.68	0.43	2						
	1989	0.04 - 0.13	0.09	2						
	1990	0.06 - 0.20	0.13	4	0.17 - 0.68	0.40	6	0.63 - 2.00	1.12	5
	1991	0.05 - 0.27	0.12	6	0.17 - 1.20	0.46	6	0.78 - 1.40	1.08	6
	1992	0.07 - 0.32	0.20	4	0.22 - 0.43	0.31	4	0.56 - 1.40	0.93	4

PLANT	YEAR	TREATED RANGE	TREATED MEAN	TREATED N	FLUSHED RANGE	FLUSHED MEAN	FLUSHED N	OVERNIGHT RANGE	OVERNIGHT MEAN	OVERNIGHT N
PRESCOTT	1990	0.16 - 0.69	0.37	8	0.28 - 0.95	0.59	7	2.10 - 14.00	5.77	7
	1991	0.40 - 1.00	0.65	11	0.24 - 0.62	0.40	11	1.79 - 8.30	4.96	11
	1992	0.43 - 0.92	0.66	4	0.23 - 0.47	0.34	4	4.20 - 5.60	4.75	4
RAINY RIVER	1991	ND - 0.57	0.11	11	0.08 - 0.33	0.14	11	0.31 - 0.68	0.46	9
	1992	0.05 - 0.64	0.15	7	0.08 - 0.19	0.13	7	0.26 - 3.20	1.06	7
RED ROCK	1991	ND - 1.10	0.22	6	0.32 - 0.66	0.48	6	2.50 - 6.10	3.45	6
	1992	0.05 - 0.12	0.07	9	ND - 0.55	0.35	9	ND - 4.60	3.16	9
RENFREW	1989	0.13 - 3.80	0.84	10	0.11 - 3.30	0.72	20	0.45 - 43.00	13.02	20
	1990	0.13 - 1.70	0.53	11	0.11 - 332.00	15.48	22	0.24 - 10.00	4.36	22
	1991	0.09 - 0.67	0.43	9	0.08 - 0.71	0.37	18	0.29 - 17.00	3.61	18
	1992	0.11 - 0.53	0.35	6	0.16 - 1.20	0.44	6	0.71 - 5.50	1.83	6
ROCKLAND	1990	0.05 - 0.15	0.09	4	0.20 - 0.71	0.45	4	0.53 - 7.80	2.75	4
	1991	0.05 - 0.18	0.11	12	0.23 0.33	0.29	9	0.30 - 41.00	8.57	9
	1992	0.08 - 0.25	0.13	4	0.27 - 7.50	2.09	4	0.32 - 5.40	2.00	4
SARNIA (LAMBTON COUNTY)	1985	3.00 - 3.00	3.00	2						
	1986	3.00 - 3.00	3.00	20	3.00 - 5.00	3.17	12	3.00 - 20.00	6.58	12
	1987	3.00 - 5.00	3.18	11	3.00 - 8.00	3.39	18	3.00 - 40.00	11.35	17
	1988	ND - 1.20	0.22	11	0.14 - 0.59	0.33	19	1.10 - 18.00	5.59	19
	1989	0.02 - 1.10	0.46	11	0.27 - 1.50	0.70	12	0.64 - 18.00	8.08	12
	1990	0.05 - 0.37	0.20	6	0.35 - 18.00	3.41	6	2.40 - 22.00	9.03	6
	1991	0.05 - 2.60	0.56	6	0.37 - 0.68	0.55	6	4.00 - 17.00	11.63	6
	1992	0.05 - 0.22	0.10	6	0.43 - 1.00	0.71	6	2.70 - 57.00	16.25	6

		TREATED			FLUSHED			OVERNIGHT		
PLANT	YEAR	RANGE	MEAN	N	RANGE	MEAN	N	RANGE	MEAN	N
SAULT STE MARIE	1987	3.00 - 4.00	3.11	9	ND - 12.00	3.47	17	ND - 14.00	7.35	17
	1988	0.02 - 0.89	0.15	12	0.17 - 12.00	1.73	22	ND - 29.00	10.90	22
	1989	0.02 - 0.17	0.07	12	0.53 - 11.00	2.04	23	5.30 - 320.00	25.30	22
	1990	0.05 - 0.10	0.08	6	0.46 - 11.00	2.25	10	1.80 - 30.00	10.84	8
	1991	0.05 - 0.09	0.07	6	0.71 - 4.20	1.78	11	3.10 - 49.00	14.22	11
	1992	0.05 - 0.07	0.06	4	0.55 - 3.60	1.74	4	5.10 - 79.00	26.00	4
SAULT STE MARIE (GOULAIS)	1987	3.00 - 3.00	3.00	1						
	1988	0.10 - 0.10	0.10	1						
	1989	0.05 - 0.05	0.05	1						
	1990	0.05 - 0.05	0.05	2						
	1991	0.05 - 0.05	0.05	1						
	1992	0.05 - 0.06	0.06	2						
SAULT STE MARIE (LORNA)	1987	3.00 - 8.00	3.67	9						
	1988	0.10 - 0.47	0.19	12						
	1989	0.04 - 0.33	0.19	12						
	1990	0.06 - 0.11	0.09	6						
	1991	0.05 - 0.98	0.24	6						
	1992	0.06 - 0.07	0.07	2						
SAULT STE MARIE (SHANNON)	1987	3.00 - 3.00	3.00	1						
	1988	0.37 - 0.43	0.40	2						
	1989	4.00 - 4.00	4.00	1						
	1990	0.77 - 3.40	2.09	2						
	1991	2.20 - 2.20	2.20	1						
	1992	1.00 - 3.30	2.15	2						
SAULT STE MARIE (STEELTON)	1987	ND - 5.00	3.00	9						
	1988	0.07 - 1.00	0.29	12						
	1989	0.06 - 0.48	0.24	- 12						
	1990	0.05 - 0.13	0.09	6						
	1991	0.05 - 1.50	0.33	6						
	1992	0.09 - 0.14	0.12	2						

		TREATED			FLUSHED			OVERNIGHT		
PLANT	YEAR	RANGE	MEAN	N	RANGE	MEAN	N	RANGE	MEAN	N
SIMCOE (FIRST AVE)	1990				0.15 - 1.20	0.37	9	0.07 - 0.96	0.46	8
	1991				0.13 - 0.62	0.31	11	0.08 - 1.10	0.61	11
	1992				0.23 - 0.23	0.23	1	0.78 - 0.78	0.78	1
SIMCOE (NORTH WEST ONE)	1990				0.59 - 2.50	1.47	9	6.90 - 23.00	11.63	8
	1991				0.80 - 2.80	1.29	11	1.60 - 31.00	10.59	11
	1992				1.10 - 1.20	1.15	2	6.70 - 7.60	7.15	2
SIMCOE WELL SUPPLY	1990	0.05 - 0.09	0.06	9						
	1991	0.05 - 4.80	0.59	11						
	1992	0.07 - 0.21	0.14	2						
SMITH FALLS	1991	0.17 - 0.34	0.25	3	4.30 - 5.80	5.00	3	3.20 - 12.00	7.60	2
	1992	0.08 - 0.34	0.19	10	2.10 - 6.40	4.20	10	2.20 - 24.00	8.63	9
SOUTH PEEL (LAKEVIEW)	1984	3.00 - 3.00	3.00	8	3.00 - 3.00	3.00	32	3.00 - 16.00	5.66	32
	1985	1.00 - 4.00	2.92	12	1.00 - 6.00	2.98	48	1.00 - 58.00	5.02	48
	1986	3.00 - 3.00	3.00	13	3.00 - 7.00	3.31	45	3.00 - 11.00	4.20	45
	1987	3.00 - 3.00	3.00	12	3.00 - 5.00	3.16	44	3.00 - 8.00	3.77	44
	1988	0.07 - 1.10	0.20	12	0.17 - 7.70	0.82	25	0.64 - 5.70	2.55	25
	1989	0.02 - 0.39	0.19	12	0.21 - 1.40	0.56	22	0.94 - 4.30	2.26	22
	1990	0.05 - 0.12	0.08	6	0.05 - 0.83	0.43	10	0.63 - 5.00	1.98	10
	1991	0.05 - 0.13	0.10	6	0.22 - 8.40	1.25	10	0.78 - 8.80	2.54	10
	1992	0.06 - 0.15	0.11	4	0.24 - 2.10	1.09	3	2.00 - 5.80	4.40	3
SOUTH PEEL (LORNE PARK)	1984	3.00 - 6.00	3.50	8	3.00 - 3.00	3.00	16	3.00 - 3.00	3.00	16
	1985	2.00 - 3.00	2.92	12	3.00 - 6.00	3.17	23	1.00 - 18.00	3.83	23
	1986	3.00 - 3.00	3.00	4	3.00 - 3.00	3.00	8	3.00 - 3.00	3.00	8
	1987	3.00 - 3.00	3.00	2						
	1988	0.02 - 0.11	0.07	9	0.13 - 0.33	0.21	8	0.53 - 11.00	2.45	8
	1989	0.02 - 0.96	0.20	12	0.08 - 2.30	0.50	11	0.28 - 1.90	0.80	11
	1990	0.05 - 0.25	0.12	6	0.10 - 0.90	0.36	6	0.27 - 2.10	1.09	6
	1991	0.05 - 0.35	0.11	6	0.08 - 0.23	0.15	5	0.21 - 1.20	0.67	5
	1992	0.05 - 0.15	0.08	4	0.05 - 0.13	0.07	4	0.08 - 0.22	0.14	4

PLANT	YEAR	TREATED RANGE			TREATED MEAN	TREATED N	FLUSHED RANGE			FLUSHED MEAN	FLUSHED N	OVERNIGHT RANGE			OVERNIGHT MEAN	OVERNIGHT N
SOUTHAMPTON	1992	0.05	-	0.40	0.16	9	0.18	-	1.20	0.70	9	3.60	-	19.00	7.19	8
ST CATHARINES	1987	3.00	-	16.00	4.63	8	ND	-	60.00	5.82	22	ND	-	12.00	3.50	22
	1988	0.02	-	0.82	0.47	12	0.05	-	0.58	0.19	23	0.43	-	2.80	0.96	23
	1989	0.38	-	6.60	1.14	12	ND	-	20.00	1.24	23	0.24	-	40.00	5.25	23
	1990	ND	-	2.60	0.63	6	0.05	-	0.29	0.12	12	0.22	-	1.80	0.93	12
	1991	0.05	-	0.48	0.20	6	0.05	-	2.50	0.34	11	0.31	-	3.10	1.23	11
	1992	0.05	-	0.26	0.12	4	0.05	-	0.13	0.09	2	0.31	-	1.50	0.91	2
ST THOMAS (ELGIN)	1987	3.00	-	6.00	3.30	10	3.00	-	5.00	3.21	19	ND	-	7.00	3.63	19
	1988	ND	-	0.19	0.06	12	ND	-	3.50	0.53	24	0.35	-	5.40	2.07	24
	1989	ND	-	0.34	0.09	12	0.15	-	1.00	0.51	23	0.67	-	5.80	2.30	23
	1990	0.05	-	0.31	0.11	6	0.13	-	1.80	0.56	12	0.98	-	9.30	3.05	11
	1991	0.05	-	0.06	0.05	6	0.09	-	0.46	0.27	12	0.09	-	2.70	1.48	12
	1992	0.05	-	2.90	0.84	4	0.33	-	0.36	0.35	4	1.00	-	2.30	1.83	4
STONEY POINT (TILBURY NORTH)	1985	1.00	-	5.00	3.00	8										
	1986	3.00	-	3.00	3.00	10										
	1987	3.00	-	3.00	3.00	2										
	1988	0.07	-	0.16	0.12	3										
	1989	0.02	-	0.22	0.12	2										
	1990	0.05	-	0.10	0.07	7	0.16	-	3.70	0.92	7	0.22	-	3.20	1.01	6
	1991	0.09	-	0.34	0.21	6	0.07	-	0.43	0.27	6	0.05	-	6.10	1.24	6
	1992	ND	-	3.06	1.52	4	0.43	-	1.90	1.04	4	0.39	-	3.60	1.44	4
STOUFFVILLE WELL SUPPLY	1987	3.00	-	5.00	3.29	7										
	1988	0.02	-	0.11	0.04	13										
	1989	ND	-	0.76	0.15	11										
	1990	0.05	-	0.17	0.09	6										
	1991	0.05	-	0.09	0.07	7										
	1992	0.05	-	0.23	0.13	4										

PLANT	YEAR	TREATED RANGE	MEAN	N	FLUSHED RANGE	MEAN	N	OVERNIGHT RANGE	MEAN	N
STRATFORD WELL SUPPLY	1991	0.05 - 0.21	0.10	3	0.23 - 1.60	0.89	5	0.77 - 7.00	3.47	4
	1992	0.05 - 0.30	0.12	5	0.12 - 0.53	0.31	4	0.85 - 18.00	6.26	4
SUDBURY (DAVID ST)	1987				0.00 - 7.00	3.29	14	ND - 23.00	10.40	15
	1988				0.82 - 3.70	1.58	13	5.30 - 78.00	18.75	13
	1991	0.21 - 0.56	0.41	6						
	1992	0.06 - 0.23	0.16	9	0.74 - 0.74	0.74	1	7.10 - 7.10	7.10	1
SUDBURY (WANAPITEI)	1987				3.00 - 7.00	3.57	14	3.00 - 11.00	5.07	14
	1988				ND - 0.69	0.35	11	0.81 - 6.90	3.00	11
	1991	0.05 - 0.48	0.12	6						
	1992	0.05 - 0.10	0.06	9						
TECUMSEH	1990	0.05 - 0.08	0.06	8	0.17 - 1.20	0.50	14	0.93 - 20.00	4.50	12
	1991	0.05 - 0.10	0.05	11	0.11 - 0.66	0.37	18	1.30 - 7.80	2.77	18
	1992	0.05 - 0.07	0.05	6	0.07 - 3.30	0.96	4	0.14 - 14.00	4.54	4
TERRACE BAY	1991	0.05 - 0.23	0.12	7	0.13 - 0.41	0.23	7	0.47 - 1.50	1.02	5
	1992	0.05 - 0.09	0.07	6	0.17 - 0.27	0.21	6	0.64 - 2.20	1.15	6
THAMESVILLE WELL SUPPLY	1988	0.02 - 0.13	0.05	11	0.40 - 3.30	1.12	11	1.50 - 19.00	7.75	11
	1989	0.02 - 0.39	0.08	12	0.37 - 3.90	1.41	12	0.89 - 220.00	63.82	12
	1990	0.05 - 0.05	0.05	9	2.40 - 6.50	4.17	9	11.00 - 120.00	45.33	9
	1991	0.05 - 0.32	0.11	6	1.30 - 2.10	1.68	6	0.70 - 26.00	12.30	6
	1992	0.05 - 0.09	0.07	2	1.10 - 1.10	1.10	2	13.00 - 37.00	25.00	2
THUNDER BAY (BARE POINT)	1988	0.02 - 0.17	0.08	4	0.20 - 4.70	0.81	12	1.10 - 6.80	2.40	12
	1989	0.02 - 0.26	0.07	11	0.00 - 3.70	1.19	16	0.19 - 8.90	2.75	15
	1990	0.05 - 0.07	0.05	11	0.56 - 4.90	1.45	16	0.54 - 100.00	10.74	15
	1991	0.05 - 0.07	0.05	7	0.45 - 1.20	0.90	11	0.61 - 120.00	22.37	9
	1992	0.05 - 0.07	0.06	4	0.52 - 1.10	0.77	3	0.72 - 0.92	0.80	3

PLANT	YEAR	TREATED RANGE	TREATED MEAN	TREATED N	FLUSHED RANGE	FLUSHED MEAN	FLUSHED N	OVERNIGHT RANGE	OVERNIGHT MEAN	OVERNIGHT N
THUNDER BAY (LOCH LOMOND)	1988	0.04 - 0.61	0.28	3	0.60 - 21.00	5.95	16	3.00 - 580.00	63.22	13
	1989	0.05 - 0.29	0.17	11	ND - 1.20	0.67	11	ND - 9.50	3.45	9
	1990	0.05 - 0.11	0.08	11	0.11 - 1.00	0.34	16	0.61 - 92.00	10.46	16
	1991	0.07 - 0.20	0.14	6	0.17 - 0.47	0.30	5	0.57 - 1.70	1.12	4
	1992	0.05 - 0.11	0.08	4	0.27 - 0.27	0.27	1	2.40 - 2.40	2.40	1
TILBURY	1990	0.05 - 0.26	0.09	8	0.00 - 1.60	0.79	8	ND - 89.00	14.17	7
	1991	0.05 - 0.34	0.10	11	0.16 - 0.54	0.33	11	0.37 - 5.30	1.01	11
	1992	0.05 - 0.07	0.05	6	0.21 - 0.72	0.44	6	0.40 - 2.50	1.23	6
TRENTON (CHESTER ROAD)	1989	0.02 - 0.38	0.17	12	0.23 - 23.00	3.53	11	1.10 - 49.00	8.50	11
	1990	0.05 - 0.22	0.10	12	0.06 - 4.00	1.38	11	0.28 - 160.00	26.08	11
	1991	0.10 - 0.65	0.21	6	0.27 - 2.00	1.04	6	2.10 - 5.70	3.42	6
	1992	0.09 - 0.38	0.19	4	0.37 - 2.70	1.32	3	1.50 - 16.00	7.53	3
	1989	0.02 - 0.45	0.14	12	0.40 - 1.60	0.85	12	0.57 - 3.80	2.17	12
	1990	0.05 - 0.17	0.07	12	0.21 - 0.73	0.46	11	0.63 - 1.60	1.25	11
	1991	0.05 - 0.20	0.08	6	0.33 - 1.90	0.71	6	0.54 - 1.20	0.87	6
	1992	0.05 - 0.05	0.05	2	0.34 - 0.60	0.47	2	0.72 - 0.77	0.75	2
UNION	1987	- 6.00	3.00	10	3.00 - 8.00	3.25	20	3.00 - 37.00	5.90	20
	1988	- 0.34	0.16	12	0.13 - 0.80	0.37	24	0.92 - 34.00	3.91	24
	1989	0.02 - 1.40	0.46	12	0.12 - 0.96	0.49	24	0.85 - 12.00	2.92	22
	1990	0.07 - 0.81	0.25	6	0.25 - 0.76	0.39	12	0.46 - 11.00	3.11	12
	1991	0.09 - 1.60	0.46	6	0.14 - 0.71	0.36	12	0.51 - 2.50	1.55	12
	1992	0.07 - 0.45	0.21	4	0.23 - 1.10	0.55	4	0.97 - 3.00	1.74	4
WALLACEBURG	1985	1.00 - 5.00	3.09	11						
	1986	3.00 - 3.00	3.00	24	3.00 - 3.00	3.00	14	3.00 - 1800	132.36	14
	1987	3.00 - 9.00	3.71	14	ND - 9.00	3.46	24	ND - 120.00	9.13	24
	1988	0.05 - 0.38	0.15	15	0.04 - 3.50	0.62	20	0.21 - 34.00	4.00	20
	1989	ND - 0.78	0.24	13	0.06 - 0.62	0.25	23	0.42 - 11.00	2.65	23
	1990	0.12 - 0.41	0.26	7	ND - 0.43	0.20	12	0.49 - 8.10	2.08	12
	1991	0.05 - 0.26	0.19	6	0.09 - 1.90	0.32	12	0.15 - 5.90	2.22	12
	1992	0.05 - 0.39	0.18	6	0.06 - 0.40	0.17	6	0.48 - 15.00	4.53	6

		TREATED			FLUSHED			OVERNIGHT		
PLANT	YEAR	RANGE	MEAN	N	RANGE	MEAN	N	RANGE	MEAN	N
WALPOLE ISLAND	1985	3.00 - 3.00	3.00	6						
	1986	3.00 - 3.00	3.00	14						
	1987	ND - 4.00	2.78	9						
	1988	0.06 - 1.60	0.41	15						
	1989	0.05 - 0.51	0.21	13						
	1990	0.07 - 0.22	0.14	6						
	1991	0.07 - 0.17	0.12	6						
	1992	ND - 0.31	0.12	6						
WATERLOO WELL SUPPLY (W7)	1991	0.05 - 0.19	0.09	11						
	1992	0.09 - 0.19	0.13	3						
	1991	0.08 - 0.18	0.12	10						
	1992	0.06 - 0.25	0.14	4						
WELLAND	1989	0.02 - 0.98	0.19	12	0.73 - 3.30	2.12	12	8.60 - 14.00	11.48	11
	1990	0.05 - 0.22	0.07	12	1.20 - 3.90	2.23	12	11.00 - 38.00	16.67	12
	1991	0.05 - 0.13	0.06	6	1.40 - 4.40	2.88	4	15.00 - 26.00	19.75	4
	1992	0.05 - 0.08	0.06	4	1.60 - 2.70	2.00	4	12.00 - 17.00	14.50	4
WINDSOR	1985	3.00 - 3.00	3.00	8						
	1986	ND - 42.00	4.65	23	3.00 - 18.00	4.00	16	3.00 - 11.00	3.81	16
	1987	3.00 - 9.80	7.56	13	3.00 - 15.00	3.63	24	3.00 - 10.00	4.46	24
	1988	0.02 - 4.90	0.54	13	ND - 400.0	17.53	24	2.10 - 1300	57.30	24
	1989	0.02 - 0.51	0.15	12	ND - 3.00	1.18	24	2.00 - 6.50	3.83	24
	1990	0.05 - 0.12	0.08	6	0.23 - 2.50	1.08	12	1.40 - 6.30	4.14	12
	1991	0.05 - 0.09	0.06	8	0.29 - 2.30	0.98	10	1.50 - 6.30	4.01	10
	1992	ND - 0.23	0.08	6	0.27 - 1.80	1.05	6	3.30 - 6.40	4.88	6

1. The analytical method for lead prior to 1988 was flame atomic absorption, the detection level was 3.00 µg/L. From 1988 Inductively Coupled Mass Spectroscopy has been the analytical method with a detection limit of 0.02 µg/L.

APPENDIX B DRINKING WATER: COST ESTIMATES FOR CORROSION CONTROL

Table B.1 Cost Estimates for Corrosion Control

MUNICIPALITY/TOWNSHIP	Households	Lime Softening			Coagulation Filtration		
		Cost (million $)	Cost/YR	per house (annual)	Cost (million $)	Cost/YR	per house (annual)
ATIKOKAN	1,898	$4.68	549,711	$289.63	$3.25	381,744	$201.13
BEAVERTON (BROCK TWP)	903	$4.68	549,711	$608.76	$3.25	381,744	$422.75
BRACEBRIDGE	2,474	$4.68	549,711	$222.20	$3.25	381,744	$154.30
BRANTFORD	30,000	$15.60	1,832,370	$61.08	$13.00	1,526,975	$50.90
CASSELMAN	871	$4.68	549,711	$631.13	$3.25	381,744	$438.28
CHATHAM	16,634	$15.60	1,832,370	$110.16	$13.00	1,526,975	$91.80
CORNWALL	18,418	$15.60	1,832,370	$99.49	$13.00	1,526,975	$82.91
DRESDEN	1,220	$4.68	549,711	$450.58	$3.25	381,744	$312.90
DRYDEN	2,760	$4.68	549,711	$199.17	$3.25	381,744	$138.31
EAR FALLS	700	$4.68	549,711	$785.30	$3.25	381,744	$545.35
ERNESTOWN (ODESSA)	389	$4.68	549,711	$1,413.14	$3.25	381,744	$981.35
FORT FRANCES	3,552	$4.68	549,711	$154.76	$3.25	381,744	$107.47
GOSFIELD SOUTH (UNION)	16,200	$15.60	1,832,370	$113.11	$13.00	1,526,975	$94.26
GRAVENHURST	2,538	$4.68	549,711	$216.59	$3.25	381,744	$150.41
GRIMSBY	5,862	$4.68	549,711	$93.78	$3.25	381,744	$65.12
GUELPH	33,200	$15.60	1,832,370	$55.19	$13.00	1,526,975	$45.99
HALDIMAND (NANTICOKE)	2,240	$4.68	549,711	$245.41	$3.25	381,744	$170.42
KENORA	4,800	$4.68	549,711	$114.52	$3.25	381,744	$79.53
KINGSTON (CITY)	21,360	$15.60	1,832,370	$85.79	$13.00	1,526,975	$71.49
KITCHENER	61,955	$15.60	1,832,370	$29.58	$13.00	1,526,975	$24.65
LINDSAY	6,204	$4.68	549,711	$88.61	$3.25	381,744	$61.53
METRO TORONTO	444,000	$182.00	21,377,652	$48.15	$182.00	21,377,652	$48.15
METRO TORONTO	180,000	$15.60	1,832,370	$10.18	$13.00	1,526,975	$8.48
METRO TORONTO	56,000	$15.60	1,832,370	$32.72	$13.00	1,526,975	$27.27
METRO TORONTO	264,000	$182.00	21,377,652	$80.98	$182.00	21,377,652	$80.98
MISSISSAUGA (LAKEVIEW)	69,600	$15.60	1,832,370	$26.33	$13.00	1,526,975	$21.94
NANTICOKE (PORT DOVER)	1,904	$4.68	549,711	$288.71	$3.25	381,744	$200.50

MUNICIPALITY/TOWNSHIP	Households	Lime Softening			Coagulation Filtration		
		Cost (million $)	Cost/YR	per house (annual)	Cost (million $)	Cost/YR	per house (annual)
NIAGARA FALLS	27,537	$15.60	1,832,370	$66.54	$13.00	1,526,975	$55.45
NORTH BAY	20,256	$15.60	1,832,370	$90.46	$13.00	1,526,975	$75.38
OTTAWA (BRITANNIA)	118,788	$15.60	1,832,370	$15.43	$13.00	1,526,975	$12.85
OTTAWA (LEMIEUX ISLAND)	89,613	$15.60	1,832,370	$20.45	$13.00	1,526,975	$17.04
PETERBOROUGH	25,178	$15.60	1,832,370	$72.78	$13.00	1,526,975	$60.65
PORT ELGIN	2,521	$4.68	549,711	$218.05	$3.25	381,744	$151.43
PORT HOPE	4,137	$4.68	549,711	$132.88	$3.25	381,744	$92.28
PRESCOTT - sep.town	1,838	$4.68	549,711	$299.08	$3.25	381,744	$207.70
RENFREW	3,166	$4.68	549,711	$173.63	$3.25	381,744	$120.58
SARNIA	36,000	$15.60	1,832,370	$50.90	$13.00	1,526,975	$42.42
SAULT STE. MARIE	32,400	$15.60	1,832,370	$56.55	$13.00	1,526,975	$47.13
SIMCOE	5,334	$4.68	549,711	$103.06	$3.25	381,744	$71.57
SMITHS FALLS	4,274	$4.68	549,711	$128.62	$3.25	381,744	$89.32
SOUTHAMPTON	1,914	$4.68	549,711	$287.21	$3.25	381,744	$199.45
SUDBURY - DAVID STREET	37,490	$15.60	1,832,370	$48.88	$13.00	1,526,975	$40.73
THAMESVILLE	394	$4.68	549,711	$1,395.21	$3.25	381,744	$968.89
THUNDER BAY (BARE POINT)	23,402	$15.60	1,832,370	$78.30	$13.00	1,526,975	$65.25
THUNDER BAY (LOCH LOMOND)	20,966	$15.60	1,832,370	$87.40	$13.00	1,526,975	$72.83
WELLAND	19,784	$15.60	1,832,370	$92.62	$13.00	1,526,975	$77.18
WINDSOR	90,000	$15.60	1,832,370	$20.36	$13.00	1,526,975	$16.97
WOOLWICH - ELMIRA	2,901	$4.68	549,711	$189.49	$3.25	381,744	$131.59
TOTAL		$820	$96.2 million		$728	$85.5 million	

APPENDIX C DERIVATION OF CONVERSION FACTORS FOR 1/2 HOUR, 24 HOUR AND 30 DAY AVERAGING TIMES FOR LEAD

The derivation of a conversion factor relating a 30 day average concentration to a 24 hour average is based on actual air monitoring data. Data from the 69 air monitoring stations which monitor for lead was used for this analysis. The arithmetic annual average for lead concentrations (an average of 40-60 individual 24 hour samples) was compared to the maximum 24 hour concentration recorded for each station. This analysis was performed separately for monitoring stations which recorded an annual average above 0.05 μg/m³ and below 0.05 μg/m³. Monitoring stations with an annual average in excess of 0.05 μg/m³ are considered to be dominated by a single source of lead. The ratio between the maximum 24 hour concentration and the annual average is provided in Table C.1.

Table C.1 Ratios for Lead Monitoring Data Between 24 hour Maxima and Long-term averages

24 Hour maximum concentration/annual average							
	n	min	max	10th percentile	25th percentile	50th percentile	Average
Stations ≤0.05 μg/m³	61	2	29	3	4	5	6
Stations >0.05 μg/m³	8	3	20	3	4	13	12

The ratios provided in Table C.1 indicate that, on average, for monitoring stations dominated by sources of lead emissions, the maximum concentration recorded was approximately 12 fold higher than the annual average recorded for the site. The annual average is determined from approximately 40-60 individual measurements which are recorded once every six days. This corresponds to 1½-2 months of continuous monitoring. A value of 3 is selected as an appropriate conversion factor since a few stations recorded a ratio of 3 or less. While this selection is biased towards the conservative end of the ratios recorded, it provides reasonable assurance that the 30 day average will not be exceeded if the 24 hour average is met.

The derivation of a factor to convert from a 24 hour average to a 1/2 hour average is similar to that described above. However, since lead concentrations are not monitored for periods of less than 24 hours, data from surrogate compounds is used for this analysis. Two compounds for which extensive short-term urban monitoring data is

available are NO_x and SO_2. Oxides of nitrogen are produced by a number of sources with large contributions from the transportation and utility sectors. Sulphur dioxide emissions on the other hand, have a major component from tall stacks such as smelters and power utilities with a relatively minor contribution from non point sources such as transportation. In general, the ratio between short term maxima and long term averages tends to be larger if emissions are dominated by single facilities and particularly those with tall stacks.

The ratios between 1 hour maxima recorded concentrations and maximum 24 hour averages for NO_x and SO_2 emissions are summarized in Table C.2.

Table C.2 Ratios for NO_x and SO_2 Monitoring Data Between 1 Hour Maxima and 24 Hour Average

1 hour maximum concentration/24 hour average							
	n	min	max	10th percentile	25th percentile	50th percentile	Average
NO_x	36	2.3	4.7 (one outlier at 9.5)	2.5	2.8	3.2	3.2
SO_2	70	1.4	10 (one outlier at 15)	2.5	3	4	4.6

The data provided in Table C.2 indicate that the average ratio between 1 hour maxima and maximum 24 hour averages for NO_x and SO_2 are 3.2 and 4.6 respectively. A factor of 3 was selected as an appropriate ratio to relate 1/2 hour averages to 24 hour averages. This again is somewhat conservative, but provides reasonable assurance that a 24 hour average will not be exceeded if the 1/2 hour criteria is met. A conversion factor of 3 takes into account the observation that monitoring data collected over 1/2 hour period are typically only 20% higher than data collected over a 1 hour period (Turner, 1970).

In summary, for lead specific sources, a factor of 3 is recommended to convert a 30 day average criteria to a criterion based on a 24 hour averaging period. Similarly, a factor of 3 is also recommended to convert from a 24 hour average criteria to a criterion based on a 1/2 hour averaging time. The use of these conversion factors will ensure that if the 1/2 hour point of impingement standard for lead is met, exceedances of the 24 hour and 30 day criteria should not occur.

APPENDIX D BENEFITS OF PREVENTING LEAD EXPOSURE IN ONTARIO

D.1 Introduction

Improvements in environmental quality yield benefits because people are better off than they were before the improvements. However, environmental improvements yield two types of benefits: public and private.

Public benefits are valuable effects of pollution abatement or prevention that benefit members of society who are not directly associated with the agencies or firms that implement and pay for the actual program. Moreover, public benefits of pollution control are **public goods** which people cannot be prevented from enjoying and which are bestowed, more or less, equally on the population and which persist to be enjoyed by future generations.

Public benefits are distinct from **private benefits** such as the recovery of saleable by-products or reduced production costs which may result when a firm invests in pollution control. Firms may also avoid the bad public relations that comes with being perceived as a major polluter. Adverse public relations could be translated into reduced revenues if customers avoid a firm's products because of the company's poor environmental performance.

Revising the environmental multi-media standards for lead in the province will yield benefits not only for the environment but also for the economic and social fabric of the area. Quantification of these benefits, where possible, is important to put the overall costs of the standard revision in some perspective and to enhance the awareness of all concerned of the numerous benefits that can result from commitment to the reduction of lead exposure.

Public benefits can be measured as:

1) reductions in current damages, including human health effects,

2) future damages avoided,

3) enhanced use and enjoyment of environmental resources.

Where possible, benefits estimates developed in this section consist of two distinct sets of information.

First, empirical estimates of the biophysical effects and consequences that result from remedial actions are presented. These estimates show explicitly the types of effects and their magnitudes in relevant biophysical units. This first set of estimates reveal how relevant biophysical data are used to determine the magnitude and distribution of the beneficial effects of a decrease in lead exposure.

Second, the monetary values associated with the various quantitative benefit categories are listed. Keeping the two sets of estimates distinct allows reviewers and stakeholders the opportunity to assign their own explicit weights or values to the relevant bio-physical benefit measures if they disagree with those that result from the use of monetary values.[2]

The use of monetary values of environmental damage or benefit estimates has the following advantages:

... 1) monetary values permit the addition of effects and consequences that are otherwise measured in diverse units;

... 2) monetary values represent the relative economic and (in some instances) social welfare associated with the various benefits, and

... 3) monetary values allow direct comparison of the value of beneficial effects with remedial action cost estimates in a benefit-cost assessment context.

This assessment of benefits of the revision of provincial lead standards is organized into 4 sections: A discussion of the approach taken; an assessment of the benefits of preventing a 1 µg/dL increase in blood lead levels of children; an assessment of the reduction in expenditures achieved by preventing children from developing blood lead levels ≥ 25 µg/dL (a level associated with classical lead poisoning); and a description of the method used to calculate the present value of lifetime earnings.

D.2 Lead, Health and the Economy

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2 Weighting units or "value measures" other than money have been suggested in the literature. However, monetary values are based on well developed theory, are widely understood and are less likely to involve assertion of researcher value judgements than non-economic weighting units.

Lead exposure and its effects among U.S. children has been estimated to impose billions of dollars annually on the U.S. economy (e.g., Levin 1986).

This analysis will focus on the benefits of preventing and reducing exposure to children under the age of 4, the population of concern in Ontario.

For purposes of this analysis, the benefits of preventing or reducing lead exposure in children are the reduced or avoided adverse effects that would have resulted had exposure occurred. Table 1, which appears in Section 2, lists some of the adverse health effects of lead exposure and the associated blood lead level.

The adverse effects listed, are only a few of the benefits of preventing lead exposure. Many benefits cannot be described in biophysical terms (e.g., avoiding the emotional disruption to families of having a lead poisoned child). Other benefits such as preventing lead's effects on children's physical development, blood pressure and as a possible human carcinogen will not be explored in this analysis. The reason is not because they are unimportant, particularly when summed over thousands of children; rather it reflects the absence of methods for estimating reliable biophysical measures of these effects.

Also not evaluated in this analysis is the improvement in property values from improved housing conditions resulting from abatement of lead paint or the effects of lead on adults such as increased rates of hypertension and stroke. By not including these effects, the estimates of lead exposure to Ontario society presented in this appendix are grossly underestimated.

For this document, a method developed by the Centers for Disease Control (CDC) for its 1991 statement on preventing lead poisoning in young children has been applied. The evaluation defines and estimates benefits arising from two scenarios. The first considers the benefits of preventing increased blood lead levels in children regardless of initial blood lead levels. Avoided productivity losses from preventing the effects of lead on intellectual functioning for increases of 1 µg/dL in blood lead levels were estimated. This scenario is considered most appropriate for understanding the potential benefits of revised environmental standards. The second scenario considers the benefits which accrue for children whose blood lead levels are prevented from rising above a certain threshold; avoided medical and special education expenditures were estimated for only those children who would have had blood lead levels ≥ 25 µg/dL. These expenditures are presented as the average expense for each child in this category and take into account that not all children with blood lead levels ≥ 25 µg/dL will need chelation therapy or special education.

D.3 The Benefits of Preventing a 1 µg/dL Increase in Blood Lead Levels of Children

Most children with lead related cognitive deficits in Ontario do not require special education or other assistance, however, their losses can still be substantial in biophysical and monetary terms. Neurobehaviourial changes, decreased cognitive abilities, IQ (Intelligence Quotient) deficits, and lower MDI (Mental Development Index) scores can reduce a person's productivity in society. The CDC's benefits analysis uses the value of reduced productivity as a proxy for the cost to society of cognitive impairment. This cost is an underestimate because it puts no value on the losses sustained by the individual that are not reflected by decreased economic productivity (e.g., the emotional disruption to the individual of having an IQ deficit). For this analysis it is assumed that the benefits of reducing lead exposure on the cognitive functioning of children exhibit no threshold.

Figure D.1 depicts the relationships CDC has envisioned between lead exposure and the value of productivity (earnings). Lead is believed to have a direct effect on cognitive abilities, as measured by changes in IQ (pathway a). This reduction in IQ then has a direct effect on wage rate (pathway b), which affects lifetime earnings (pathway f). Lead also affects earnings as a result of reduced educational attainment which results from reduced cognitive abilities and decreased attention span (pathway c). The effect of educational attainment on earnings is traceable through two main pathways. First wage rates are directly proportional to educational attainment and therefore, with lifetime earnings (pathway d). Second, educational attainment is also associated with labour force participation (pathway e), which again has an effect on lifetime earnings (pathway f').

The CDC devised and applied the following system of equations to calculate the total reductions in earnings because of lead exposure.

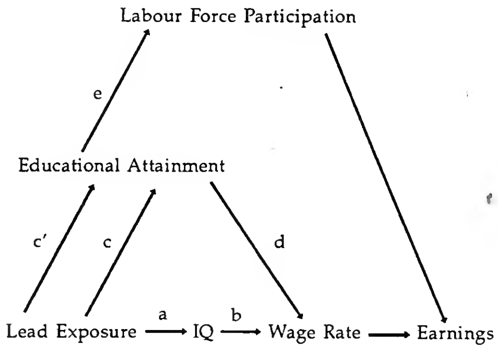

Figure D.1 Effect of Lead Exposure on Earnings (Source: The Centers for Diseases Control, 1991)

First, the change in wage rate was estimated given a 1 μg/dL change in blood lead level.

$$a^* b^* = 0.25 \text{ points}/\mu g/dL^* 0.5 \text{ \%/point} \qquad \textbf{[Equation D.1]}$$

$$= 0.125 \text{ \%}/\mu g/dL$$

where:

a = estimated change in IQ for each 1 μg/dL change in blood lead level. (0.25 IQ points per 1 μg/dL change in blood lead levels obtained by weighting the inverse of the variance of estimates from six studies relating blood lead levels to IQ decrements).

b = estimated percentage change in wage rate for a 1 IQ point change (0.5% wage change per IQ point). The CDC used Griliches' 1977 study which employed structural equations modelling to estimate the direct effect of IQ on wage rate.

Second, the average change in wage rate from the decreased educational attainment resulting from lead exposure was estimated.

$$a*c*d = 0.25 \text{ points}/\mu g/dL * 0.131 \text{ years/point} * 6\%/\text{year} \quad \textbf{[Equation D.2]}$$

$$= 0.197 \ \%/\mu g/dL$$

where:

a = as above

c = estimated change in years of schooling attained for a 1 IQ point change (0.131 years of schooling per 1 IQ point change resulting from lead exposure) estimated by the CDC based on studies by Needleman *et al.* (1990) and Needleman and Gatsonis (1990).

d = estimated percentage change in wage rate for a one year change in years of schooling attained [6% per year of schooling based on studies by Chamberlain and Griliches (1977) and Olneck (1977)].

Third, the average change in wage rate from decreased labour force participation from failure to graduate from high school was estimated.

$$a*c'*e = 0.25 \text{ points}/\mu g/dL * 4.5\%*10.5\% \quad \textbf{[Equation D.3]}$$

$$= 0.118 \ \%/\mu g/dL$$

where:

a = as above

c′ = estimated change in the probability of graduating from high school for a 1 IQ point change resulting from lead exposure (4.5% increased probability of failure to graduate for each 1 point decrease in IQ). The CDC used the study of Needleman *et al.* (1990) to derive this estimate.

e = estimated percentage change in labour force participation because of failure to graduate from high school (10.5% decrease in labour force participation because of failure to graduate) estimated using regression coefficients in a study by Cropper and Krupnick (1989).

Finally, aggregating the information; the change in expected present value of lifetime earnings from a 1 μg/dL change in blood lead levels can be expressed as follows:

$$\Delta E = E(ab) + (acd) + (ac'e) \qquad \textbf{[Equation D.4]}$$

where:

ΔE = the expected change in lifetime earnings from exposure to lead
E = the net present value of lifetime earnings

The CDC estimated a net present value benefit of $1,147 (U.S. 1989$'s) per child for the prevention of an increase of 1 μg/dL in a child's blood lead level.

For our purposes, estimated lifetime earnings in Ontario was calculated using earnings data collected by Statistics Canada (Catalogue 13-207, 1991). Section D.3 contains the formula describing the basic method and assumptions used to prepare the estimate. Employing this method, the net present value of average lifetime earnings per child, discounted to age 4 in 1993 dollars is estimated to be $420,802.

Solving for ΔE, a net present value lifetime benefit estimate of $1,852 per child for the prevention of an increase of 1 μg/dL in a child's blood lead level is obtained.

ΔE= $420,802 x [0.125+0.197+0.118] %/μg/dL

D.4 The Reduction in Expenditures Achieved by Preventing Children from Developing Blood Lead Levels ≥ 25 μg/dL

To estimate the average medical expenses that would be incurred for each child with a blood lead level ≥ 25 μg/dL, the CDC devised and applied the following equation which multiplied the medical expense by the associated probability of requiring treatment.

$$AMC = PFU (\$FU) + PEDTA (\$EDTA) + PCHEL (\$CHEL) \qquad \textbf{[Equation D.5]}$$

where:

AMC = average medical expenditure per child ≥ 25 μg/dL in dollars
PFU = probability of receiving follow-up testing for children ≥ 25 μg/dL
$FU = expenditure for follow-up testing per child
PEDTA = probability of receiving provocative session of EDTA testing and follow-up

$EDTA	=	expenditure for EDTA testing and follow-up per child
PCHEL	=	probability of receiving chelation therapy per child
$CHEL	=	expenditure for chelation therapy per child

The CDC estimated that $1,300 (U.S. 1989$'s) in total medical costs could be avoided by preventing a child from developing a blood lead level above 24 µg/dL during their lifetime.

Ontario Medical Expenses

Ontario Ministry of Health officials and health care professionals indicate that follow up tests and administrative expenditures for all children whose blood lead levels are ≥ 25 µg/dL total $203 per child[1] ($FU). This analysis assumes that all children identified with blood lead ≥ 25 µg/dL levels will receive medical attention in the form of at least testing and follow-up (PFU =1).

The CDC, citing Piomelli *et al.*, indicate that 70% (PEDTA) of children with blood lead levels ≥ 25 µg/dL will have erythrocyte protoporphyrin levels ≥ 35 µg/dL and will receive provocative calcium disodium edetate (EDTA) testing, one form of chelating treatment and follow-up. Provocative EDTA testing costs $113 per vial for the chelating agent and requires a follow-up procedure and one night of hospitalization to administer. The total estimated cost of the treatment to $828 $EDTA).

The CDC indicates that 5% of children with blood lead levels ≥ 25 µg/dL will receive chelation therapy. Half of these (2.5%) will require a second chelation therapy because their blood lead levels will rebound to ≥ 25 µg/dL. Half of these (1.25%) will require a third round of chelation therapy. Adding the probabilities, an average of 0.0875 (PCHEL) chelation therapies will be required for every child with a blood lead level of ≥ 25 µg/dL.

The Hospital Medical Records Institute of the Ministry of Health assigns Resource Intensity Weights to estimate the expense of treating patients with particular diseases relative to a standard patient expense. Using this method, and adding the expense of

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[1] $38.00 - general visit to GP
$106.00 - specialist
$21.00 - lab test
$38.00 - follow-up visit to GP

Total $203.00 - Testing and Follow-up

the chelating agent and follow-up procedures required, the cost of each chelation therapy is estimated to be $4,138 per patient ($CHEL).

Applying the CDC equation to the information above gives a total medical expenditure of $1,445 (AMC) that can be avoided by preventing a child in Ontario from developing a blood lead level above 24 μg/dL.

$$1{,}445 = (1)(203) + (0.7)(828) + (0.0875)(4{,}138)$$

Expenditures for Special Education

Children with high blood lead levels are more likely to have decreased school performance and require remedial reading or speech therapy or psychological assistance. The CDC devised and applied the following equation to compute the expenditures on of special education as a result of lead exposure leading to blood lead levels ≥ 25 μg/dL.

$$ASEC = (PSE)(\$SE)$$

where:

ASEC =	special education expenditures per child with blood lead levels ≥ 25 μg/dL
PSE =	probability of child with blood lead levels ≥ 25 μg/dL requiring special education
$SE =	current expenditures on special education

Based on a number of reports[2], the CDC indicates that 20% (PSE) of children with blood levels ≥ 25 μg/dL will require special education (defined as assistance from a reading teacher, school psychologist or other specialist) for an average of three years. Base level funding for Special Education Programs in 1993 from the Ontario Ministry of Education is listed as $3,970 per elementary student ($PSE) (Ontario Ministry of Education, 1993). This is the per pupil amount allotted by the Ministry of Education to school boards to fund special education needs for each pupil. The actual expenditure is probably higher as funds allocated as base amounts for all elementary

[2] de la Burde and Choate (1975)
Bellinger et al. (1984)
Needleman et al. (1990)
Lyngbye et al. (1990)
Schwartz et al. (1985)

students are often drawn upon to deliver special education programs as the need arises. Thus, the \$3,970 amount is a conservative estimate.

Because costs would be incurred over three years, costs in year 2 and 3 are discounted at 5%[3] to the year special education begins. The average special education costs for Ontario children with blood lead levels $\geq 25\ \mu g/dL$ in year 1 is \$794 = (0.20)x(3,970). Discounting years 2 and 3 by 5% results in total special education expenditure of approximately \$2,270 per child with a blood lead level $\geq 25\ \mu g/dL$ (ASEC).

D.5 Determination of Net Present Value of Lifetime Earnings

To calculate the **net present value of lifetime earnings**, a number of assumptions are required. First, dollars available in the future must be discounted to the present. The principle behind discounting is that there is a social as well as a personal preference for postponing costs and obtaining benefits as soon as possible. Therefore, a dollar available in the future is valued less than a dollar available today. Discounting thus has the effect of reducing the numerical value of benefits and costs occurring in the future. A 5% real discount rate is used because it is consistent with experience over the past decade.

The second assumption is that the real wage growth due to productivity increases in the future will be 1% per annum for the 1993 distribution of incomes. The assumption is a conservative one because historically, productivity increased by 1.9% in Canada between 1980 and 1990. The Ontario Ministry of Finance and a number of other organizations have forecast productivity growth in the future of between 1% and 2%.

The following formula describes the basic method used to prepare the estimate presented in Section D.1 of the present value of expected earnings for a 4 year old in Ontario through to age 77 which is the average life expectancy of Ontarians[4].

V_4 - the present value of the total sum of earnings received between age 4 and age 77

[3] A 5% real discount rate is consistent with experience over the past decade.

[4] Weighted average life expectancy of males + weighted average life expectancy of females. Relative labour participation rates were used as weights. Source: Ontario Ministry of Finance, *Ontario Economic Outlook*. October 1992

$$V_4 = \sum_{N}^{77} \frac{Y_N (1+X)^{N-4}}{(1+r)^{N-4}}$$ **[Equation D.6]**

Y_N - the average annual earnings at age N. Estimates were obtained from Statistic Canada. Catalogue 13-207, *Income Distributions by Size in Canada, 1991*

X - assumed annual increase of 1% in earnings due to productivity increases. This factor is added to the equation to allow for the fact that in a growing economy individuals may expect an upward trend in their earnings. It is an adjustment for the growth in productivity in the economy not for the inflation. It is assumed that real wage growth in the future will be 1% per annum

r - the rate of discount used to convert future earnings to their present values. A discount rate of 5% was used.